# CORNELL UNIVERSITY ANNOUNCEMENTS

# COLLEGE OF ENGINEERING

THE SCHOOL OF CIVIL ENGINEERING
THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING
THE SCHOOL OF ELECTRICAL ENGINEERING
THE SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING
THE DEPARTMENT OF ENGINEERING PHYSICS
AGRICULTURAL ENGINEERING
THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

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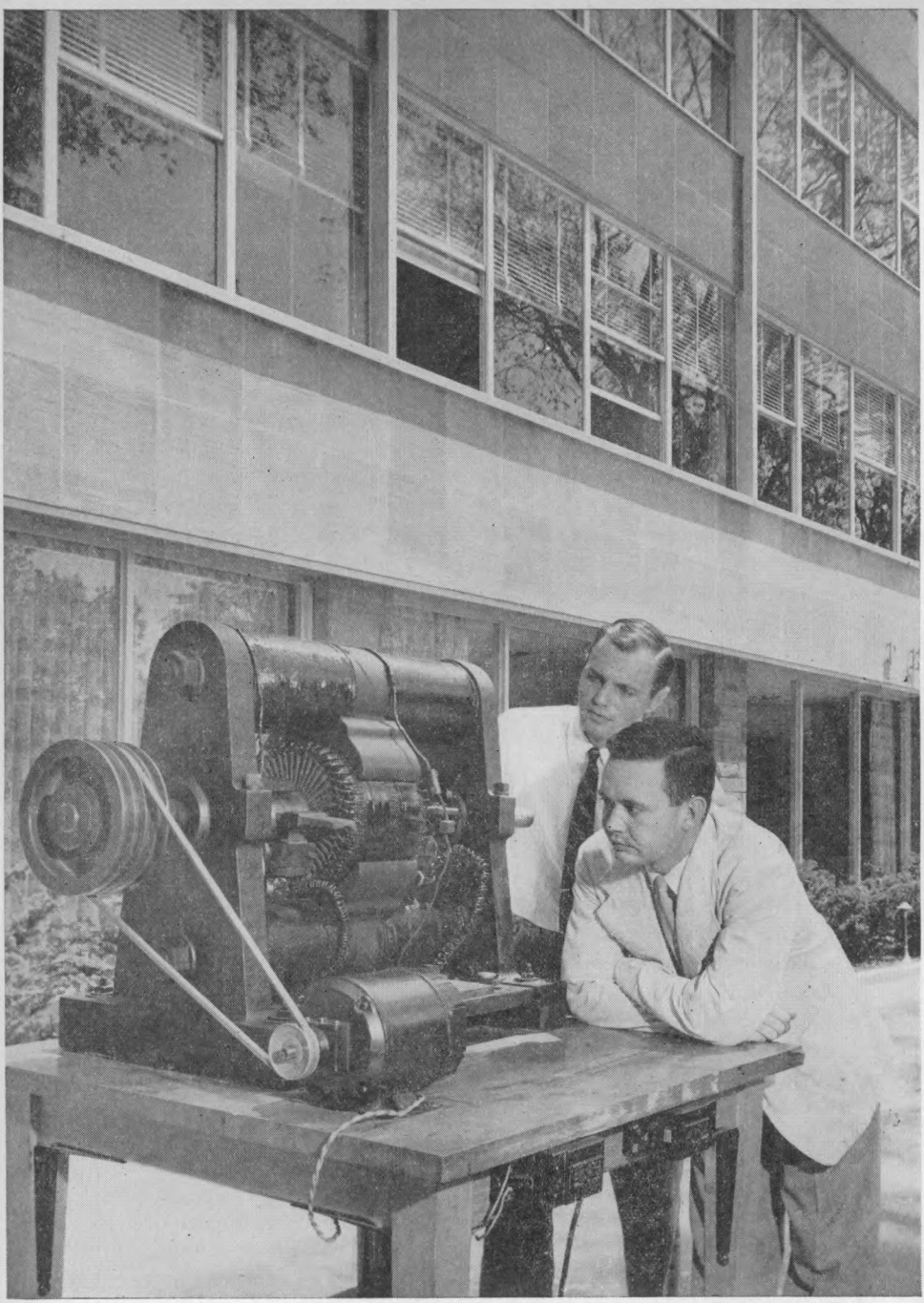


*THE OLD AND THE NEW: MORE THAN SEVENTY-FIVE YEARS OF CORNELL ENGINEERING*

*Shown at the entrance of Phillips Hall of electrical engineering (1955) is the historic dynamo that gave the Cornell campus outdoor electric lights in 1878, the first such permanent lighting system in America.*

# THE COLLEGE OF ENGINEERING

## ORGANIZATION AND HISTORY

THERE ARE two principal types of engineering colleges in America today. One is a self-contained unit stressing science and technology, often referred to as a technological institute. The other, of which the College of Engineering at Cornell is an example, is that subdivision of a university which emphasizes technological education but, in the development of its curricula, is able to call upon the educational resources of other programs of professional and nonprofessional study. At Cornell these other areas of study include agriculture, architecture, arts and sciences, business and public administration, home economics, hotel administration, industrial and labor relations, and law.

Engineering has had an important place in the program of Cornell University from the beginning. The Federal Land Grant, or Morrill Act of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to...the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities. This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. In 1883 Cornell opened courses in electrical engineering, among the first to be offered anywhere in America; and in 1919, when the Board of Trustees formed the present College of Engineering, the School of Electrical Engineering was established. Courses in Chemical Engineering were organized in 1931, and seven years later the School of Chemical Engineering was established to supervise the curriculum which leads to the degree of

Bachelor of Chemical Engineering. A course in metallurgical engineering has now been added, and the name of the school has been changed to the School of Chemical and Metallurgical Engineering. In 1946 the Graduate School of Aeronautical Engineering was founded. The same year the Department of Engineering Physics was started. Finally, in 1952, a professional curriculum in agricultural engineering was established as a joint program with the College of Agriculture.

## CURRICULA AND DEGREES

*UNDERGRADUATE STUDY* is available in these divisions of the College: The School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, the School of Chemical and Metallurgical Engineering, and the Department of Engineering Physics. A course in professional agricultural engineering is given in cooperation with the College of Agriculture.

*GRADUATE STUDY* is available in the Engineering Division of the Graduate School of the University (including the schools and departments listed above and the Department of Mechanics and Materials) and in the Graduate School of Aeronautical Engineering.

Cornell University confers the following degrees on the successful completion of undergraduate courses of study in the College of Engineering: Bachelor of Civil Engineering (B.C.E.); Bachelor of Mechanical Engineering (B.M.E.); Bachelor of Electrical Engineering (B.E.E.); Bachelor of Chemical Engineering (B.Ch.E.); Bachelor of Metallurgical Engineering (B.Met.E.); Bachelor of Engineering Physics (B.Eng.Phys.); Bachelor of Agricultural Engineering (B.Agr.E).

The advanced degrees of Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) are granted by the University on the recommendation of the Faculty of the Graduate School.

The degree of Master of Aeronautical Engineering (M.Aero.E.) is granted on the recommendation of the Faculty of the Graduate School of Aeronautical Engineering.

## OBJECTIVES

An engineering career has its roots in science and technology, but in its breadth it touches many areas of human activity. The purpose of Cornell engineering and of Cornell life is to create a balanced experience that will serve the engineer in the full range of his future progress. In his studies the Cornell engineer builds a broad foundation of fundamentals in the basic sciences, in basic engineering applications, and in modern technology, much of which is given substance in extensive laboratory practice. He follows a major branch of engineering, avoiding the limitations imposed on future development by narrow specialization—in fact, he studies fundamentals in the adjacent areas

of engineering in anticipation of a wide scope of future activities. This broad basic approach has enabled a considerable number of Cornell engineers to develop opportunities outside their original fields of study and experience and to gain distinction in complex enterprises requiring the coordination of many and varied activities.

The further development of this kind of background is supported by the inclusion of a solid core of liberal, general, and managerial studies throughout the period of his technical studies. By including the equivalent of a full year's work in these studies in the five years of engineering training, the young engineer achieves a broadened philosophy and understanding as a natural part of his professional background.

Formal academic work occupies a substantial part of each student's time; nevertheless, it is only a part. Beyond this are the opportunities of university life that form a distinctive influence in personal development and that should be a primary objective in the plan of each student for a collegiate experience of maximum effectiveness. We are particularly happy that the Cornell engineer can study and live in an atmosphere that is not only of strong engineering aspect but that is charged as well with the vitality of a university community dedicated to scholarship in the whole range of human endeavor. He carries with him, therefore, not only the components of his own learning, but also the intellectual stimulation of his association with the university community and the spiritual influence of the University's natural setting. Much of the Cornell tradition has been shaped of these factors; much of the purpose of Cornell engineering gains substance through their effect.

It is our aim to make available to the students who have shown the aptitude, character, and high determination for engineering study at Cornell all of the elements of knowledge, experience, and inspiration that will make for notable achievement in a long professional career.

## THE CORNELL FIVE-YEAR PROGRAM

Cornell requires five years for the completion of undergraduate study in the branches of engineering for which it offers degrees. This departure from the traditional four-year curricula results from the conviction that in no shorter time can a sound and adequate technological training and the necessary acquaintance with the liberal arts be achieved.

Engineering problems grow more difficult and complex, and engineering technology continues to expand. At the close of World War I, we were still using Model T Fords; airplanes were still called "crates"; there was no transcontinental air service for passengers, mail, or express; radio was in its infancy, and there was no television; there were no high-speed diesel locomotives; and many of the developments that came about during World War II were not even dreamed about,

such as radar, UHF and VHF communication, guided planes and missiles.

It is true that a considerable amount of engineering work can be done successfully today with the training that was provided twenty-five years ago. On the other hand, if the engineers of the next quarter-century are to be able to cope with the maintenance and advancement of the expanding technological system that characterizes the world today, they must surely be better trained in mathematics and the basic sciences. Equally important for the engineer of today and tomorrow is the need for greater acquaintance with the social sciences and the humanities which will help prepare him for his role as citizen and for leadership in a complex society.

These requirements of engineering education cannot be met by further compressing the already crowded curricula of yesterday. As law and medicine achieved professional maturity, they of necessity expanded, and continued to expand, their training programs. Engineering must do likewise.

Some engineering colleges have tried to meet this challenge by r-ranging combination courses in cooperation with liberal arts colleges which provide for three years in a liberal arts college followed by two years of technological training in an engineering college. This expedient highlights the fundamental distinction between the independent liberal arts college and the independent technical school, on the one hand, and, on the other, a university community in which one finds several diverse fields of undergraduate study. Engineering education today demands a bringing together into one integrated program of instruction both technical and nontechnical subjects.

At Cornell, the blending of liberal arts and engineering is accomplished at all levels of instruction in such a manner as to take full advantage of the proper sequences of courses, and this is possible because Cornell is able to provide, on one campus, educational opportunities in both fields. The Cornell engineering student acquires an early acquaintance with engineering. He also is able to obtain part of his preparation in liberal arts in the later years of his program when added maturity and a broader base of knowledge make certain subjects more meaningful to him.

The "three and two" combination curricula offered by some institutions are an approximation of this integrated program of arts and engineering, limited primarily by geographical separation and the difficulties inherent therein.

The Cornell engineering curricula are composed of four principal categories of subjects:

(1) Basic Science (mathematics, physics, chemistry).
(2) Applied engineering science (mechanics, properties of materials, thermodynamics, electrical theory, etc.)

(3) Applied technology (structural design, hydraulics, industrial engineering, electronics, power, chemical operations, and similar subjects related to modern engineering practice).
(4) General, managerial, and liberal studies (English, history, management, psychology, public speaking, economics, law, and such additional subjects in the several divisions of the University as the student may elect).

The distribution of courses from these categories varies with each curriculum, but in general the basic science and applied engineering science are presented in the first half and applied technology in the latter half. The nonscientific, nontechnological subjects are to be found throughout the five years.

The courses in liberal arts or other nontechnical fields which each student is either required or may elect to study comprise about one-fifth of each curriculum. In some curricula the majority of such courses is prescribed; in others the majority is elective. In all of them a student will spend the equivalent of about one year of his five on subjects outside the fields of engineering, mathematics, and science.

## ADMISSION

### PROCEDURE AND REQUIREMENTS

All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Cornell University, Ithaca, New York, who will forward the necessary application blanks on request.

Detailed information concerning the requirements for admission and methods of procedure are outlined in the University's *General Information Announcement,* which every candidate for admission should read carefully and which can be obtained by application to Cornell University Announcements, Edmund Ezra Day Hall, Ithaca.

Entrance subjects must include English (four units), elementary and intermediate algebra (two units), plane geometry (one unit), and trigonometry (one-half unit). A foreign language (two units) *or* history (two units); advanced algebra (one-half unit) *or* solid geometry (one-half unit); and chemistry (one unit) *or* physics (one unit) must also be offered. It is strongly recommended that at least three of the elective units offered to make up the balance of sixteen be in language or history. Applicants are also advised to offer advanced algebra rather than solid geometry, when a choice is possible. Candidates for admission to the School of Chemical and Metallurgical Engineering are required to have chemistry (one unit).

Each candidate for admission is required to take the Scholastic Aptitude Test of the College Entrance Examination Board and to request the Board to report the results to the Director of Admissions, Cornell

University. Candidates are urged to take the test in January of their senior year.

The number of applicants admitted to the several schools of the College of Engineering is limited by the facilities available for adequate instruction. The committees on admissions in each of the Schools will exercise discretionary power in selecting those to be admitted. Preference will be given to those candidates whose academic preparation and personal character indicate fitness to pursue with success the course of study to be undertaken, who show evidence of professional promise, and who complete the filing of their entrance credentials in ample time for the committee to give thorough consideration to their qualifications.

## CHOICE OF CURRICULUM

Every applicant for admission is asked to designate the branch of engineering he wishes to study, namely, civil engineering, mechanical engineering, electrical engineering, chemical engineering, metallurgical engineering, or engineering physics. Each branch has its own curriculum which carries its own professional degree.

The first year of study is essentially the same for all branches and includes mathematics, physics, chemistry, English, and appropriate courses in descriptive geometry or drafting. This similarity of the curricula in the freshman year makes it possible for students to transfer from one division to another of the College without great hindrance when for one reason or another a change of objective is desirable. Thus, no applicant in his first year need feel that by committing himself to a particular branch of engineering education he has made an irrevocable decision.

After the second year, as the several curricula begin to diversify, transfer within the College of Engineering is somewhat more difficult and in a few instances may necessitate an additional term or more of study.

Applications for transfer should be made to the Director of the prospective school during the term preceding the one in which the student wishes to change his course, and students should realize that the earlier such transfers are made the fewer will be the resulting complications of curricular adjustment.

# SPECIAL PROGRAMS OF STUDY

## THE INDUSTRIAL COOPERATIVE PROGRAM

During the fourth term of the regular curriculum students in electrical and mechanical engineering who are in good standing may apply for admission to the Industrial Cooperative Program.

The Cooperative Program provides three work periods of term length (about 16 weeks each) in one of the following industries operating the plan with the University: American Gas and Electric Service Corpora-

tion, Air Reduction Company, Cornell Aeronautical Laboratory, General Electric Company, International Business Machines Corporation, Philco Corporation, and Procter and Gamble.

By utilizing the three summer periods after the fourth term (normally vacation periods), Cooperative students are enabled to complete all the academic work regularly required for the Bachelor's degree and can graduate with their regular classes. The schedule is as follows after Term 4:

| *Period* | *Term* | *Term* | *Term* |
|---|---|---|---|
| Summer | 5 | Industry | 8 |
| Fall | Industry | 7 | 9 |
| Spring | 6 | Industry | 10 |

It is to be noted that the Cooperative student remains with his regular classmates during all terms on campus except the fifth and eighth, which he takes in the summer. The Cooperative Program therefore is not an accelerated program and involves a minimum of departure from the regular program.

Although the student is on the industry payroll during the work periods, the function of the plan is educational rather than to provide part-time employment. The work in industry is coordinated with the student's studies so far as practicable and provides an invaluable opportunity for him to direct his study interests on campus toward the realities of his future environment. Supervision is provided for each student, both from campus and industry, to ensure his obtaining optimum benefit from the Program. Many students have found this a profound influence on their objectives and on their progress both before and after graduation.

Applications for the Cooperative Program are accepted in the fourth term only. Applicants are subject to approval both by the College and by one of the cooperating industries. Admission to the plan involves no obligation on the part of either the student or the industry with regard to future employment.

## COMBINED PROGRAMS IN LAW, BUSINESS AND PUBLIC ADMINISTRATION, AND CITY AND REGIONAL PLANNING

During the fourth year of the regular curriculum students in good standing in some divisions of the College of Engineering may apply for admission to special programs which will permit the completion of requirements for both the appropriate Bachelor's degree in engineering and one of the advanced or graduate degrees in law, business and public administration, or city and regional planning, in one year less than the normal period.

Ordinarily such a combined program, leading to two degrees, would

constitute an eight-year course of study in the case of law and seven years in the case of business and public administration or city and regional planning. By choosing as electives courses acceptable to the other schools or colleges and by being permitted to count certain other courses as meeting requirements in both areas, students will be able to acquire the two degrees in the shortened period.

Arrangements for one or more such combined programs of study are possible for selected students in chemical, civil, electrical, and metallurgical engineering. Applications will be accepted at any time prior to the fifth year, but, for maximum flexibility and ease of program planning, the choice should be made as early as possible. Applications must be approved by both participating schools or colleges in any instance.

## UNDERGRADUATE STUDIES IN AERONAUTICAL ENGINEERING

Applicants interested in the field of aeronautical engineering should apply for admission to the School of Mechanical Engineering, the School of Electrical Engineering, or the Department of Engineering Physics. In the regular five-year programs of these Schools they will obtain the fundamental scientific and humanistic courses that an aeronautical engineer must have; in addition, they may elect aeronautical engineering courses in the Graduate School of Aeronautical Engineering during their fourth and fifth years (provided that their scholastic record at that time is adequate). They can also carry out Senior Projects in the aeronautical field, under the direction of staff members of the School of Aeronautical Engineering. By planning their programs in this way, these students obtain an unusually sound and well-rounded aeronautical engineering education, combining the broad engineering training of Cornell's five-year undergraduate curricula with specialized aeronautical studies of the type usually reserved for graduate students.

Applicants should mention their interest in aeronautical engineering when they apply for admission. The Director of the Graduate School of Aeronautical Engineering will assist them in planning their fourth and fifth-year programs so as to take greatest advantage of the offerings of that School.

## NUCLEAR POWER

An elective program planned to prepare men for work in the nuclear power field is available for qualified students in the divisions of Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering, and in Engineering Physics. Based on the premise that engineers will be the most productive in the nuclear power field if they are able to apply their particular field of engineering in combination with a sound knowledge of nuclear physics and related technical subjects, the pro-

gram provides for a series of elective courses in the fourth and fifth years, including atomic and nuclear physics, laboratory work in nuclear measurements, principles and design of nuclear reactors, advanced heat transfer and diffusion, reactor materials, radiation damage, fuel processing, waste disposal, etc. The student interested in the nuclear power field should consult with his adviser for assistance in planning a program of courses to take advantage of the excellent opportunities available.

## ENGINEERING LIBRARY

This library maintains working collections in the fields which it serves. Each year the most important new books are added to its stacks, as well as current issues of engineering journals and transactions and proceedings of many learned societies.

The library of the Schools of Civil, Mechanical, and Electrical Engineering in Sibley Dome includes, in addition to the regular collection, the following collections and facilities: The Kuiching Memorial Library and the support of the Irving Porter Church Fund in Civil Engineering; the Diederichs Memorial Library in Mechanical and Electrical Engineering and the James F. Lincoln Arc Welding Foundation Library in Mechanical Engineering; and the Alexander Gray Memorial Library in Electrical Engineering.

The School of Chemical and Metallurgical Engineering in Olin Hall has an unusually complete library in chemistry, chemical engineering, and metallurgical engineering.

A complete library of collections in physics and applied physics with large reading rooms is maintained in Rockefeller Hall as the Physics Branch of the University Library.

## GRADUATE STUDIES

A graduate of this College or of other colleges of engineering may enter the Graduate School of Cornell University and pursue advanced work in engineering. Such a student may enter either as a candidate for a degree (M.S. or Ph.D.) or without candidacy for a degree, according to the character of his previous training. A prospective graduate student should consult the *Announcement of the Graduate School* and apply to the Dean of the Graduate School. Information concerning graduate scholarships and fellowships, including the John McMullen Graduate Scholarships, can be obtained either from the Dean of the Graduate School or from the Dean of the College of Engineering.

Prospective candidates for the degree of M.Aero.E. should apply directly to the Director of the Graduate School of Aeronautical Engineering.

## COLLEGE AND UNIVERSITY REQUIREMENTS

### College Requirements

*FOR GRADUATION* . . . Baccalaureate degrees are conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have satisfied the University requirements in military training and physical education and in the payment of tuition and fees.

2. He must have completed to the satisfaction of the Faculty of the College of Engineering all the subjects and the elective hours prescribed in the course of study as outlined by that Faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.

4. Each student in the first term of the freshman year in the College of Engineering must attend regularly the lectures in orientation for students in engineering.

*REQUIREMENTS CHANGEABLE* . . . The College of Engineering reserves the right to modify its curricula and specific courses of instruction, to alter the requirements for admission or for graduation, and to change the degrees to be awarded; such changes are applicable to either prospective or matriculated students at any time the College may determine.

### University Requirements

*MILITARY SCIENCE* . . . All physically qualified undergraduate men who are American citizens must take military science during their first four terms. Enrollment in and satisfactory completion of the basic course of military science and tactics or air science, or the first two years of naval science, satisfies this requirement. Students transferring to Cornell from other institutions are exempt from part or all of the requirement, according to the number of terms of residence in college before transfer; and active service in the armed forces also satisfies the military training obligation. Entering students who have had ROTC training in secondary or military schools are requested to bring DD Form 68 (Student's Record—ROTC) for presentation to the Military Department at the time of registration (see also page 111 of this Announcement).

*PHYSICAL EDUCATION* . . . All undergraduate students must pursue four terms of work, three hours a week, in physical education. Ordinarily, this requirement must be completed in the first two years of residence; postponements are to be allowed only by consent of the University Faculty Committee on Requirements for Graduation.

Exemption from this requirement may be made by the committee designated above, when it is recommended by the medical office or when unusual conditions of age, residence, or outside responsibilities require it.

For students entering with advanced standing, the number of terms of physical education required is to be reduced by the number of terms which the student has satisfactorily completed (whether or not physical education was included in his program) in a college of recognized standing.

### Payments to the University

*TUITION AND OTHER FEES* . . . For information concerning tuition and other fees payable to the University, see the *General Information Announcement.*

## STUDENT PERSONNEL SERVICES

### Student Personnel Office

The admission of new students, the administration of scholarships in the College of Engineering, and the placement of graduates are activities of the College which are coordinated in the Student Personnel Office. The Personnel Office, in addition to other facilities, is also available at all times to students who wish to discuss any question relating to their life in the College.

### Student Counseling

In general, the counseling of students rests with the Class Advisers to whom the students are assigned primarily for assistance in planning and scheduling their academic work. In each School of the College, students are referred to the chairman of the scholarship committee when in financial need and to a placement adviser for assistance in vocational choice and postgraduate employment. Also, the students are free to consult with the Dean, Directors, department heads, and instructors not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Men and Dean of Women and their staffs may be consulted by students regarding their nonacademic problems. Both Deans have offices in Edmund Ezra Day Hall, Room 133.

### Health Services and Medical Care

These services are centered in the University Clinic or out-patient department and in the Cornell Infirmary or hospital. Students are entitled to unlimited visits at the Clinic; laboratory and X-ray examinations indicated for diagnosis and treatment; hospitalization in the Infirmary with medical care for a maximum of 14 days each term; and

emergency surgical care. The cost for these services is included in the College and University general fee. For further details, including charges for special services, see the *General Information Announcement.*

### Assistance to Foreign Students

The University maintains on its staff a Counselor to Foreign Students, whose duty is to look after the welfare of all students from other countries. He may be consulted on personal problems, social questions, or any other matter in which he may be helpful. His office is in Edmund Ezra Day Hall, Room 144. It is suggested that all foreign students write him before coming to Ithaca or call on him immediately upon arrival.

### Freshman Orientation

A series of orientation lectures is given to students in the fall term of the freshman year in the College of Engineering. The primary purpose of these lectures is to acquaint the student with the scope of each of the major fields of engineering and with the opportunities and the responsibilities of men in the engineering professions.

## SCHOLARSHIPS, PRIZES, AND FINANCIAL AID

### Freshman Scholarships

General awards, open to entering students in *any* undergraduate division of the University, are described in the Announcement entitled *Financial Aids and Scholarships.* They include the Cornell National Scholarships, the LeFevre Scholarships, and the University Tuition Aid Scholarships. The scholarships described below are available *only* to students entering the College of Engineering.

Application blanks for all freshman scholarships may be obtained directly from the Scholarship Secretary, Office of Admissions, Edmund Ezra Day Hall.

*ALFRED P. SLOAN NATIONAL SCHOLARSHIPS* . . . (Established by the Alfred P. Sloan Foundation.) Open to men entering any division of the College of Engineering. Annual award varies from a prize scholarship of $200 to as much as $2,000, depending upon financial need. Tenure, not limited. Six scholarships awarded annually. Applicants will be selected on the basis of high character, sound personality, leadership potential, and scientific promise.

*LOCKHEED NATIONAL ENGINEERING SCHOLARSHIP*. . .(Established by the Lockheed Leadership Fund.) Open to entering students in the College of Engineering. Annual award, tuition and fees and $500. Tenure, renewable for three additional years. One award each year to a student who is in a field of engineering applicable to the aircraft industry and whose total personal qualities can be expected

upon graduation to offer a significant contribution to the aircraft industry.

*WILLIS H. CARRIER SCHOLARSHIP* . . . (Established by the Carrier Foundation, Inc.) Open to entering students in the Sibley School of Mechanical Engineering. Annual award $750. Tenure, not limited. Selection is based on scholastic promise and financial need.

*MARTIN J. INSULL SCHOLARSHIP* . . . (Gift of Mrs. Virginia Insull, his wife.) Open to men, only, entering the College of Engineering. Annual award, $1,200. Tenure, not limited. Further provisions as for the McMullen Regional Scholarships (see below), except that serious financial need is an essential criterion. (Not available in 1956.)

*JESSEL STUART WHYTE SCHOLARSHIP* . . . (Gift of Mrs. Anna Jessel Whyte in memory of her son.) Open to an entering student in the Sibley School of Mechanical Engineering. Annual award, $820. Tenure, not limited. Preference will be given to residents of Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Further provisions as for McMullen Regional Scholarships (see below). (Not available in 1956.)

*JOHN McMULLEN REGIONAL SCHOLARSHIPS* . . . (Gift under the will of John McMullen.) Open to men, only, entering any division of the College of Engineering. Annual award, up to $1,000. Tenure, not limited. Forty or more scholarships awarded annually. Applicants will be selected on the basis of high scholastic achievement and other indications of qualities likely to produce leadership in engineering. Although financial need is not a factor in selecting the winners, full consideration will be given to need in fixing stipends.

*JOHN McMULLEN INDUSTRIAL SCHOLARSHIPS* . . . (Gift under the will of John McMullen.) Open to male secondary school graduates with at least one year's apprentice training in industry, who are sponsored by their employers. Terms otherwise as for John McMullen Regional Scholarships.

*EDWARD P. BURRELL SCHOLARSHIPS* . . . (Gift under the will of Katherine W. Burrell, in memory of her husband.) Open to men and women entering any division of the College of Engineering. Award, $400 for freshman year only. Need is an important factor in selecting the winners.

### Scholarships and Grants-in-Aid for Upperclassmen

Students in their sophomore year and beyond may apply for scholarship aid through the Committee on Scholarships of the School in which they are enrolled (i.e., Civil Engineering, Mechanical Engineering, etc.). Applications are available in the office of the Director of each School.

Awards are of two general types: (1) those for which the principal qualification is financial need, and (2) those for which outstanding scho-

lastic achievement is the chief criterion. In the first category are scholarships which are essentially grants-in-aid and which have variable stipends up to full tuition in any year. Eligibility extends to any student not on scholastic probation.

The second category of awards, based on high scholastic and other attainments, consists of (1) a limited number of scholarships sponsored by industrial companies, mostly for students in their last two years of study, and (2) such vacancies as may occur in scholarships of this type usually awarded to entering students and subject to renewal. For some of these scholarships the stipends may be $1,000 a year; for others the amounts may vary from token awards of $100 to $1,500 or more annually.

### Loans

The University maintains substantial loan funds from which students may borrow after they have been in residence for two terms and provided they are in good standing. Loans bear no interest while the student is in the University, and usually not more than 4 per cent annually after he leaves until repayment is made. Applications for loans should be made through the Office of the Dean of Men and Dean of Women.

### Part-Time Campus Employment

Students wishing to earn a part of their living expenses by working on or near the campus during the school year should apply in advance of registration to the office of the Dean of Men and Dean of Women in Day Hall. Freshmen are advised to meet their first year expenses by other means if possible, until by experience they have learned how much time they will have available to devote to such employment.

### Prizes

Cornell University has a considerable number of funds given for the endowment of prizes to be awarded annually. Some of these prizes are open to competition by students of the University generally. A list of them, under the title *Prize Competitions,* will be mailed on request addressed to Cornell University Announcements, Edmund Ezra Day Hall. Prizes open to competition particularly by students of the College of Engineering are:

*THE FUERTES MEDALS,* established by the late Professor E. A. Fuertes. The endowment provides for two gold medals. One is awarded annually by the Faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of this course, provided he has been in attendance at the University for at

least two years. The other is awarded annually by the Faculty to a graduate of the School of Civil Engineering or the recipient of a graduate degree with major in civil engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the Faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction.

*THE FUERTES MEMORIAL PRIZE IN PUBLIC SPEAKING,* founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of $100, one of $40, and one of $20, are offered annually to all students of the Colleges of Engineering and Architecture who are in the fifth term or beyond, for proficiency in public speaking.

*THE CHARLES LEE CRANDALL PRIZES,* founded in 1916 by alumni of the School of Civil Engineering; prizes of $75, $50, $35, and $20. They are awarded each year by a committee appointed by the Director of the School of Civil Engineering for the best papers written by seniors or juniors in that School on suitable subjects, provided that both the substance and the written form of the papers submitted show real merit. The prizes were established to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before March 15 of each year.

*SIBLEY PRIZES.* Under a gift of Hiram Sibley, made in 1884, the sum of $100 is awarded annually in several prizes to fifth year students in mechanical engineering and electrical engineering, equally distributed, who have received the highest average in the preceding four years.

*THE SILENT HOIST AND CRANE COMPANY MATERIALS HANDLING PRIZES* of $125 and $75, established in 1950 by the Wunsch Foundation, are awarded each year for the best original papers on the subject of materials handling. This contest is open to undergraduate and graduate students of the College of Engineering.

*THE J. G. WHITE PRIZE IN SPANISH.* Through the generosity of James Gilbert White (Ph.D., Cornell, '85), three prizes, established in 1914, each of the value of $100, are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the Col-

lege of Engineering who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University.

*THE INSTITUTE OF AERONAUTICAL SCIENCES PRIZE.* The "Student Branch Scholastic Award" of the Institute of Aeronautical Sciences is presented annually to the M.Aero.E. candidate who attains the best scholastic record for that academic year. The award consists of a certificate and a two-year free technical membership in the Institute.

### Graduate Scholarships and Fellowships

Graduate students whose major subjects are in the various branches of engineering and who wish to be candidates for scholarship or fellowship aid should consult the *Announcement of the Graduate School* and make application to the Dean of the Graduate School or, for those who are candidates for the degree M.Aero.E., to the Director of the Graduate School of Aeronautical Engineering.

## STUDENT HONORS AND ACTIVITIES

### Dean's Honor List

Students of the College of Engineering whose weighted average in their studies is 85 per cent or better are included annually in an Honor List compiled for the Dean. The honor students comprise approximately the highest tenth of all the students enrolled in the College.

### Student Activities

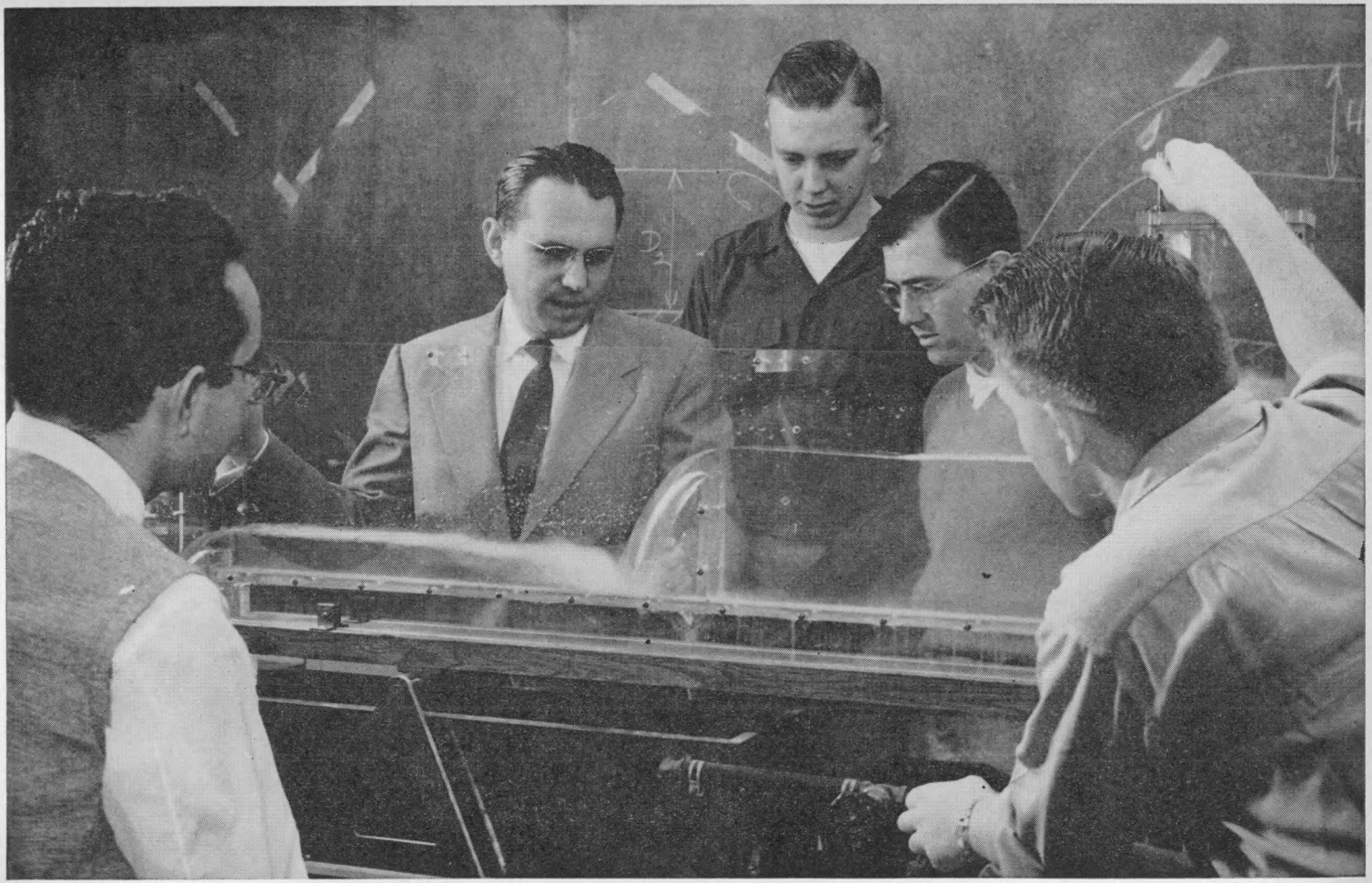
Students of the College of Engineering find many opportunities for engaging in wholesome activities outside their regular duties, and even outside the College, in company with other members of the University community. Within the College some find congenial occupation in helping to carry on the student branches of the national engineering societies, in conducting *The Cornell Engineer,* or in membership in national or local honor societies, which include Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Pi Tau Sigma, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu. In the University at large there are student activities of all sorts—musical, dramatic, journalistic, social, and athletic.

### Engineering Societies

The College of Engineering is closely associated with the local sections of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Automotive Engineers, and Institute of Radio Engineers,

many of the meetings of which are held on the campus and are participated in by the members of the College. The College also maintains active student branches of these national societies as well as of the American Institute of Chemical Engineers and the Institute of Aeronautical Sciences. The Cornell Metallurgical Society was formed in 1949 and is an affiliate of the American Institute of Mining and Metallurgical Engineers. Students in the Department of Engineering Physics formed in 1948 the Cornell Society of Engineering Physics. The meetings of such societies afford opportunities for addresses by engineers of eminence, for the presentation of papers by students, for discussion, or for contests in public speaking on engineering subjects. The School of Mechanical Engineering gives elective credit hours for activity in the student branches of the A.S.M.E.

*THE CORNELL ENGINEER,* a technical journal published monthly throughout the academic year, is managed and edited by undergraduates in the College of Engineering.



# SCHOOL OF CIVIL ENGINEERING

THE PROFESSION of civil engineering pertains to the design, construction, and maintenance of major buildings, bridges, dams, airports, thruways, railways, canals, tunnels, pipelines, etc. Advanced civil engineering includes such work as the planning and administration of systems of transportation, flood control, city management, soil and water conservation, resource development, and sanitation.

About half of the graduates from civil engineering serve the public as federal, state, or city employees. The other half are widely distributed and are found in such employment as private consulting, construction management, and engineering design for engineering organizations. Future opportunities should be excellent because of expanding needs for civil engineers and the relatively small number of high school students which have elected this field as a profession since World War II.

## EQUIPMENT

The principal building occupied by the School of Civil Enginering is Lincoln Hall, containing classrooms, drafting rooms, and laboratories.

The laboratories for sanitary engineering, airphoto analysis, and photogrammetric work are located in Lincoln Hall. The sanitary laboratory provides for physical, chemical, and bacteriological analyses of water and sewage and for research in general. The airphoto analysis and photogrammetric laboratories provide for interpretation and use of airphotos in all types of surveying and regional planning activities.

A fully equipped and manned machine shop is also provided in Lincoln Hall, which gives support to laboratory instruction and research.

Facilities in Thurston Hall include the testing laboratory, equipped for a wide variety of tests of cement, concrete, timber, structural steel, and other construction materials used by civil engineers.

The soil mechanics laboratory is located in a separate building and has facilities for instruction, standard laboratory work, and specialized research in soil mechanics.

The highway laboratories are housed in separate buildings and are equipped for making standard tests and for research in highway engineering. Astronomical equipment in the Fuertes Observatory includes the instruments required for determining time, latitude, longitude, and azimuth.

Hydraulic laboratories, situated at the outlet of Beebe Lake, are under the jurisdiction of this School. In addition to student instruction and research, these laboratories provide facilities for hydraulic investigations carried on in cooperation with government agencies and private companies.

## COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degree of Bachelor of Civil Engineering. The courses are all planned to provide fundamental instruction for the practice of the profession. To meet this objective, the major portion of the curriculum is definitely prescribed, both as to technical content and humanistic studies. Each student, however, is permitted to choose elective courses in various fields which can be planned to intensify his training in a specific area or to increase his general background.

*COMBINED PROGRAMS* . . . The School participates with the Law School, the Graduate School of Business and Public Administration, and the College of Architecture (City and Regional Planning) in combined programs during the fifth year; in this way the student in civil engineering may complete the requirements for the appropriate advanced or graduate degree in a period one year less than that normally required. The programs are described on pages 28 and 29.

## CURRICULUM (B.C.E.)

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 1 | Mathematics 161, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 115, Mechanics | 3 | 3 | 2½ |
| | Chemistry 105, General Inorganic Chemistry | 3 | 2 | 3 |
| | English 111, Introductory Course | 3 | 3 | 0 |
| | Engineering 2001, Drawing | 3 | 0 | 7½ |
| | Total | 15 | | |
| TERM 2 | Mathematics 162, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 116, Wave Motion, Sound, and Heat | 3 | 3 | 2½ |
| | Chemistry 106, General Inorganic Chemistry | 3 | 2 | 3 |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Engineering 2002, Drawing | 3 | 0 | 7½ |
| | Engineering 2111, Elementary Surveying | 2 | 0 | 5 |
| | Total | 17 | | |

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 3 | Mathematics 163, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 113, Electricity and Magnetism | 2 | 3 | 2½ |
| | Chemistry 301, Organic Chemistry or Chemistry 402, Physical Chemistry | 2 | 2 | 0 |
| | Geology 113, Engineering Geology (or Economics 105) | 3 | 2 | 5 |
| | Engineering 2112, Advanced Surveying | 3 | 2 | 2½ |
| | Engineering 1151, Mechanics-Statics | 3 | 3 | 0 |
| | Total | 16 | | |
| TERM 4 | Physics 114, Physical Electronics and Optics | 2 | 3 | 2½ |
| | Chemistry 402, Physical Chemistry or Chemistry 301, Organic Chemistry | 2 | 2 | 0 |
| | Economics 105, Modern Economic Society or Geology 113 | 3 | 3 | 0 |
| | Engineering 2113, Route and Aerial Surveying | 3 | 1 | 5 |
| | Engineering 1152, Mechanics-Dynamics | 3 | 3 | 0 |
| | Engineering 1153, Strength of Materials | 3 | 3 | 0 |
| | Total | 16 | | |

In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.

| | | | | |
|---|---|---|---|---|
| | Engineering 2114, Summer Survey Camp | 5 | 0 | 0 |
| TERM 5 | Engineering 1134, Strength of Materials | 3 | 3 | 0 |
| | Engineering 1211, Materials (or 2901) | 3 | 2 | 2½ |
| | Engineering 2301, Fluid Mechanics | 3 | 3 | 0 |
| | Engineering 2501, Microbiology in Engineering (or 2725) | 3 | 2 | 2½ |
| | Engineering 2701, Elementary Structural Analysis | 3 | 2 | 2½ |
| | Engineering 2602, Transportation (or Accounting 3231) | 3 | 3 | 0 |
| | Total | 23 | | |
| TERM 6 | Engineering 2901, Construction Methods (or Materials 1211) | 3 | 3 | 0 |
| | Engineering 2302, Hydraulics | 3 | 2 | 2½ |
| | Engineering 3231, Accounting (or 2602) | 3 | 2 | 2½ |
| | Engineering 2702, Elements of Metals and Timber Structures | 3 | 0 | 7½ |
| | Engineering 1145, Applied Mathematics | 3 | 3 | 0 |
| | Engineering 2725, Soil Mechanics (or 2501) | 3 | 2 | 2½ |
| | Total | 18 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 7 | Engineering 1212, Materials Laboratory (or 2412) | 3 | 1 | 5 |
| | Engineering 2704, Statically Indeterminate Structures (or Speech 101) | 3 | 3 | 0 |
| | Engineering 2502, Water Supply and Treatment (or 2503) | 3 | 2 | 2½ |
| | Engineering 2715, Reinforced Concrete Design (or 2610) | 3 | 1 | 4 |
| | Engineering 2902, Engineering Law (or 2903) | 3 | 3 | 0 |
| | Socio-Economic elective | 3 | 3 | 0 |
| | Total | 18 | | |
| TERM 8 | Engineering 2412, Hydraulics (or Materials 1212) | 3 | 3 | 0 |
| | Engineering 2503, Sewerage and Sewage Treatment (or 2502) | 3 | 2 | 2½ |
| | Engineering 2720, Foundations (or 2904) | 3 | 2 | 2½ |
| | Engineering 2610, Highway Engineering (or 2715) | 3 | 2 | 2½ |
| | Engineering 2903, Economics of Engineering (or 2902) | 3 | 3 | 0 |
| | Public Speaking 101 (or 2704) | 3 | 3 | 0 |
| | Total | 18 | | |
| TERM 9 | History 165, Science in Western Civilization | 3 | 3 | 0 |
| | Engineering 2713, Structural Design (or 2720) | 3 | 0 | 6 |
| | Engineering 3541, Heat Power I | 3 | 2 | 2 |
| | Engineering 4931, Electrical Engineering | 3 | 2 | 2½ |
| | Electives (Free) | 6 | | |
| | Total | 18 | | |
| TERM 10 | Engineering 3542, Heat Power II | 2 | 2 | 0 |
| | Engineering 4932, Electrical Engineering | 3 | 2 | 2½ |
| | Engineering 2904, Public Administration (or 2713) | 3 | 3 | 0 |
| | History 166, Science in Western Civilization | 3 | 3 | 0 |
| | Industrial and Labor Relations 293, Survey of Industrial and Labor Relations | 3 | 3 | 0 |
| | Electives (Free) | 6 | | |
| | Total | 20 | | |

Grand total for ten terms: 181 credit hours including summer survey camp, but not including military training or physical education.

## COMBINED PROGRAMS

### CIVIL ENGINEERING AND BUSINESS AND PUBLIC ADMINISTRATION (B.C.E. and M.B.A. or M.P.A.)

During the fifth year the student will be registered in both Schools. A specialized program will be worked out with the Graduate School of

Business and Public Administration within the framework of the Civil Engineering curriculum as amended by the following approved substitutions:

BPA, 110, Administrative Accounting, for Eng. 3231

BPA 140, Finance, for Economics 203.

BPA 120, 121, Economics and Business History, for History 165, 166

BPA 100, 101, Administration, for Eng. 2904 and ILR 293

Under special circumstances, and by petition to the Faculty, other substitutes may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered only in the Graduate School of Business and Public Administration.

## CIVIL ENGINEERING AND CITY AND REGIONAL PLANNING (B.C.E. and M.R.P.)

After approval by both the School of Civil Engineering and the College of Architecture, the fifth year student may follow a special program within the framework of the Civil Engineering curriculum as amended by the following approved substitutes:

BPA 218, Municipal Administration, for Eng. 2904

Arch. 700, 401, History of Architecture and City Planning, for History 165, 166

Arch. 710, 711, Principles and Practice of City Planning, for Econ. 203 and ILR 293

Arch. 718 or 720, Field Problems in Urban Planning, for three elective courses

Under special circumstances, and by petition to the Faculty, other substitutes may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered in the College of Architecture as a candidate for the M.R.P. degree.

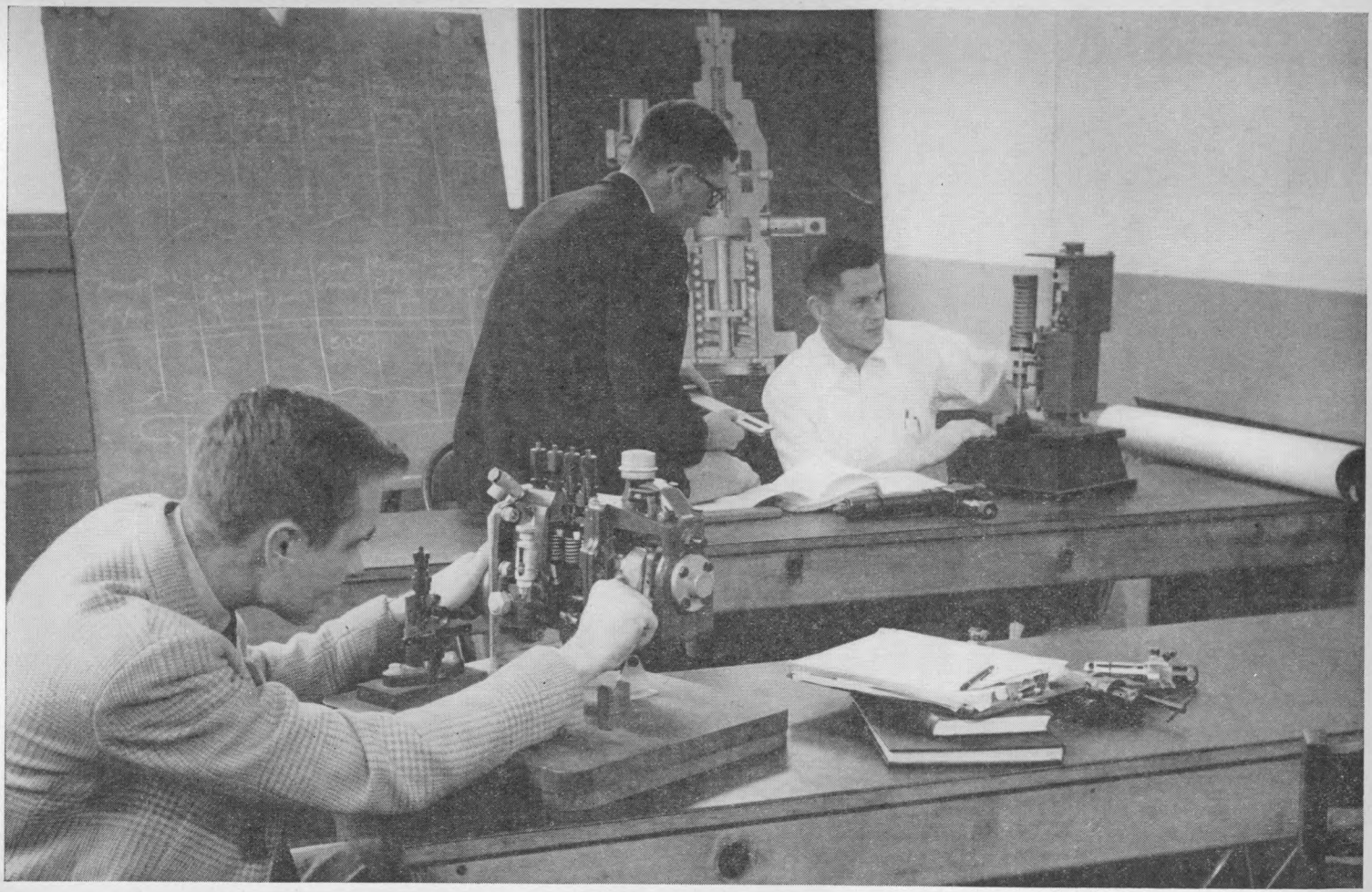
## CIVIL ENGINEERING AND LAW (B.C.E. and LL.B)

During the fifth year, the student will be registered in both schools. He will follow a specialized program including at least twenty semester hours in the Law School and within the framework of the Civil Engineering curriculum as amended by the following approved substitutions.

Twenty credit hours of Law School courses may be substituted for the fifteen elective hours and any two of the required courses, Engineering 2713, 2902, 2904, or History 166.

Under special circumstances, and by petition to the Faculty, other substitutions may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered only in the Law School.



# SIBLEY SCHOOL OF MECHANICAL ENGINEERING

## EQUIPMENT

THE SIBLEY SCHOOL of Mechanical Engineering, named in recognition of important gifts made by Hiram Sibley and his son, Hiram W. Sibley, occupies a group of buildings at the north end of the campus. In addition to the Sibley building, the new Kimball Hall, housing all equipment related to materials processing, is now available at the south end of the campus adjacent to the new Thurston Hall for engineering mechanics and materials testing. The school is provided with a central working library in Sibley Dome, and many of the departments also maintain special working and reference libraries.

Numerous laboratories and shops are available for carrying on the many activities of the School of Mechanical Engineering, as follows: the materials testing laboratory, heat treatment laboratory, and metallography laboratory, for determination of the physical properties of engineering materials under various conditions; the machine design laboratory, for instruction and research in photoelasticity, balancing, vibration, stress, lubrication, and wear of machines and machine members; the steam laboratory, for instruction and research involving steam power; the internal-combustion engine laboratory, for work with this type of power equipment; the M.E. hydraulics laboratory, a pump-operated laboratory for hydraulic problems; the lubrication laboratory, for determination of the physical properties of lubricants; the refrigeration laboratory, for the study of refrigeration; the fuel testing laboratory, for determination of the composition and calorific value of all types of fuel; the micromotion laboratory, for motion and time study; the constant-temperature room, and the heat transfer, heating, ventilating, air conditioning laboratories; a series of research laboratories; the materials processing laboratories—the woodworking and pattern shop, the machine shop and the gage laboratory; the laboratory boiler house; and the University heating plant and power house.

## OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay as broad and substantial a foundation of general and technical knowledge and pro-

vide as much training in engineering practice in the fields of mechanical engineering and engineering administration as can well be imparted in a school.

Students of mechanical engineering are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, steam generating apparatus, and power plant auxiliaries, internal combustion engines, hydraulic machines, pumping engines, railway equipment, compressed-air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries. In addition, the mechanical engineer may engage in scientific research in the innumerable branches of this field.

The general plan of the curriculum is to give a thorough training in mathematics and the basic sciences of physics and chemistry leading to the fundamental engineering sciences and technological courses. Parallel with this training are a group of courses in the social sciences and liberal fields to develop a better understanding of the social, political, and economic world in which the engineer must assume responsibility for leadership. The outline of the course of study shows how the training is integrated as well as the depth and scope of the subject matter to give the young engineer a sound foundation for his future professional growth.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

## PROJECT AND ELECTIVES

During the last three years, provision is made for the choice of elective courses and a senior project in the student's major field of study. His project may be an individual one or a group project in a technical, managerial, or related field for the purpose of applying to one or more basic problems the fundamental concepts he has been taught in the preceding years and for the purpose of developing the ability to do work of an original nature.

The project may be in any one of many branches, such as management, industrial engineering, thermal engineering, internal combus-

tion engines, heat engineering, heating, ventilating and air conditioning, refrigeration engineering, automotive engineering, aeronautical engineering, mechanical design, experimental stress analysis, design development, advanced mechanics and strength of materials, engineering materials, experimental engineering, materials processing, tool engineering, welding design, structural engineering, physics, nuclear engineering, electrical engineering, and other fields related to mechanical engineering.

The 35 hours of electives in the curriculum provide an opportunity for the student to select a wide variety of courses offered in the University, depending upon his interests and objectives. To ensure a reasonable breadth of training in fields other than engineering, beyond those courses already specified, the student must elect twelve credit hours of work from the fields of English, government, history, languages, philosophy, psychology, economics, sociology and anthropology, speech and drama, literature, music, fine arts, or the classics. To acquire some depth of training, it is strongly urged that a student take at least six credit hours of work in a given field.

A minimum of eleven credit hours of electives must be approved courses in the College of Engineering. Usually these courses will be related to the student's project, but he does have the opportunity to pursue engineering specialties of great interest to him.

## INDUSTRIAL AND ENGINEERING ADMINISTRATION

The training of engineers for the field of production engineering or industrial engineering has been an integral part of the Sibley School of Mechanical Engineering for the past fifty years. The increasing scientific developments underlying the operation of works and plants in many industries have put additional emphasis on the need for a sound background in such areas as materials, design, statistical procedures, materials processing, gaging and inspection, methods engineering, cost accounting and production engineering including product analysis, plant layout, engineering economy, and production control, all of which are required in the curriculum.

The emphasis is on the engineering aspects, with due regard for the importance of the human and personnel factors involved in successfully organizing and managing an industrial enterprise.

The student interested in this field can select suitable electives to further his training in such areas as psychology, industrial marketing and research, advanced statistics for quality control and analysis, personnel management, industrial organization, advanced methods engineering, production control, and operations research, or additional work in economics or in standard costs and control.

The existence of a School of Industrial and Labor Relations, a College of Arts and Sciences, and other divisions of the University on the

same campus as the College of Engineering makes possible combinations of elective courses that are available at few other technical schools in the country.

## PREPARATION FOR AERONAUTICAL ENGINEERING

The program leading to the degree M.Aero.E., described on pages 60–63 of this Announcement, usually requires three or four terms of graduate study. Candidates for the B.M.E. degree may be able to complete the entire program in a total of six academic years by starting their aeronautical courses during their fourth and fifth years. This saves from one term to a year of residence. To accomplish this a candidate should select his elective courses from the M.Aero.E. program and should also, if possible, carry out a fifth year project in a related subject. This should be planned in consultation with the Class Adviser and a member of the Aeronautical Engineering Faculty. The privilege of taking graduate courses is restricted to undergraduates who fulfill the requirements stated on pages 62–63.

## INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program providing periods of industrial experience interspersed among regular terms of study. The Program is described on pages 12–13.

## EMPLOYMENT AFTER GRADUATION

Graduates in mechanical engineering find employment in the design, construction, testing, and operation of prime movers and other machinery, and of complete plants in their own related fields, and in sales engineering and industrial research and development. They serve also as planners of new projects and processes, and as aeronautical engineers, air-conditioning engineers, industrial engineers, power-plant engineers, refrigeration engineers, research engineers, and teachers of engineering —to mention only a few of the many special fields open to them. With the instruction in liberal subjects and those related to administration and management coupled with the technical training, they have special qualifications to develop into leaders in their chosen fields.

## SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who fails in any term to earn a passing grade in 15 hours, with a grade of 70 or better in 11 hours, may be placed on probation. If he fails in any term to pass 12 hours he may be dropped from the School.

## CURRICULUM (B.M.E.)

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 1 | Mathematics 161, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 115, Mechanics | 3 | 3 | 2½ |
| | Chemistry 105, General Inorganic Chemistry | 3 | 2 | 3 |
| | English 111, Introductory Course | 3 | 3 | 0 |
| | Engineering 3111, Drawing and Descriptive Geometry | 3 | 1 | 5 |
| | Engineering 3001, Introductory Engineering | 1 | 2 | 0 |
| | Total | 16 | | |
| TERM 2 | Mathematics 162, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 116, Wave Motion, Sound, and Heat | 3 | 3 | 2½ |
| | Chemistry 106, General Inorganic Chemistry | 3 | 2 | 3 |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Engineering 3112, Mechanical Drafting | 3 | 1 | 5 |
| | Engineering 3002, Introductory Engineering | 2 | 2 | 0 |
| | Total | 17 | | |

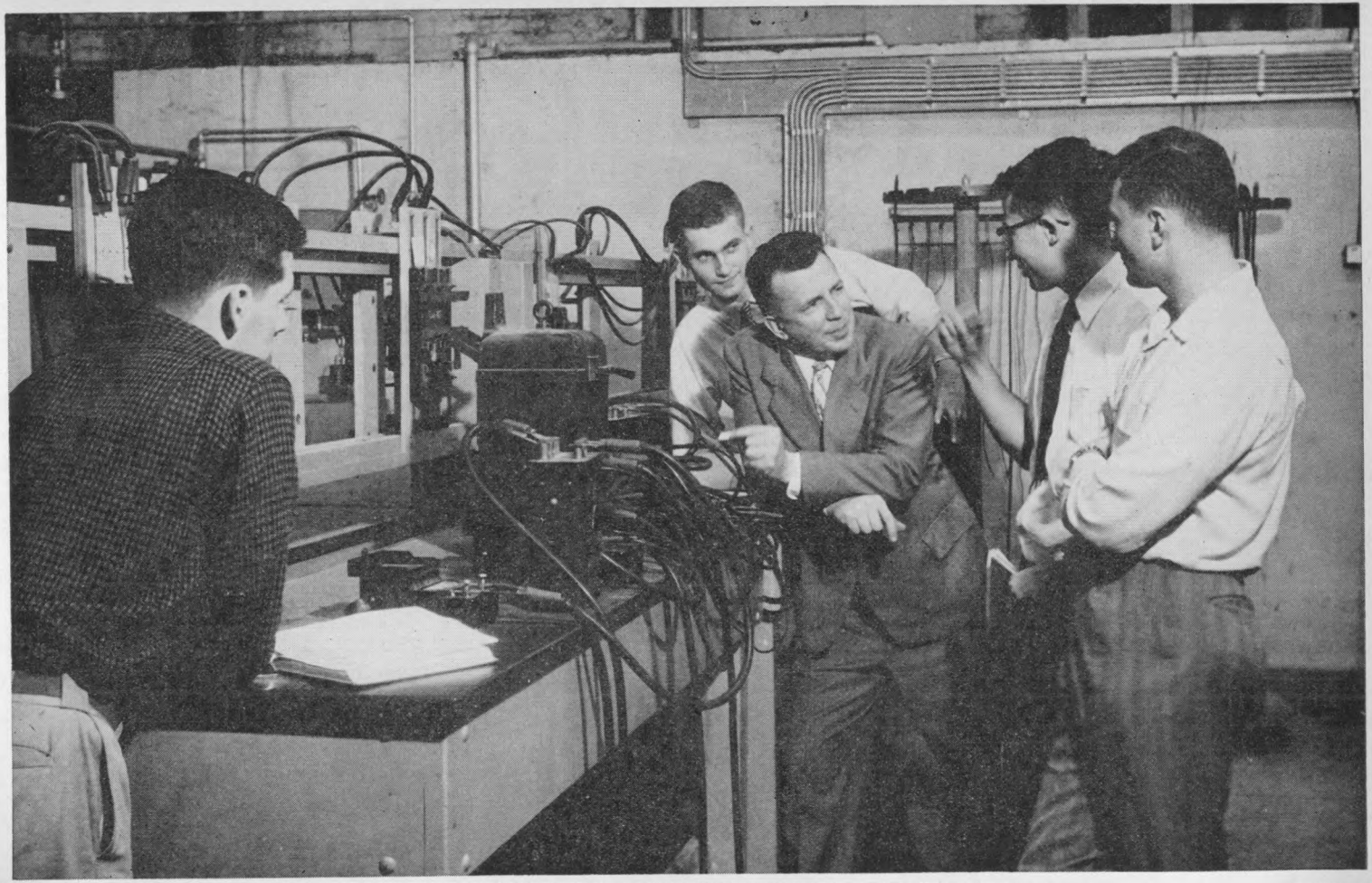
In addition to taking these courses, all freshmen must satisfy the University requirements in physical education and in military training.

| | | | | |
|---|---|---|---|---|
| TERM 3 | Mathematics 163, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 117, Electricity and Magnetism | 3 | 3 | 2½ |
| | Chemistry 301, Organic Chemistry | 2 | 2 | 0 |
| | Engineering 1151, Mechanics—Statics | 3 | 3 | 0 |
| | Engineering 3241, Statistics | 3 | 2 | 2½ |
| | Engineering 6110, Casting, Working, and Welding of Metals (or Engineering 3406) | 2 | 1 | 2 |
| | Total | 16 | | |
| TERM 4 | Physics 118, Electronics and Optics | 3 | 3 | 2½ |
| | Chemistry 402, Physical Chemistry | 2 | 2 | 0 |
| | Engineering 1153, Strength of Materials | 3 | 3 | 0 |
| | Engineering 1155, Applied Mathematics | 3 | 3 | 0 |
| | Engineering 3262, Methods Engineering | 3 | 1 | 5 |
| | Engineering 3406, Materials Processing (or Engineering 6110) | 2 | 1 | 2½ |
| | Total | 16 | | |

In addition to taking these courses, all sophomores must satisfy the University requirements in physical education and in military training.

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 5 | Engineering 1221, Engineering Materials | 3 | 3 | 0 |
| | Engineering 3351, Mechanism | 3 | 2 | 2½ |
| | Engineering 3601, Thermodynamics | 3 | 2 | 2½ |
| | Engineering 1152, Mechanics—Dynamics | 3 | 3 | 0 |
| | Engineering 3246, Industrial Accounting | 2 | 1 | 2½ |
| | Engineering 3404, Production Machine Tools (or Engineering 3405) | 2 | 1 | 2½ |
| | Electives | 3 | Arr. | Arr. |
| | Total | 19 | | |
| TERM 6 | Engineering 1222, Engineering Materials | 3 | 3 | 0 |
| | Engineering 3352, Dynamics of Machinery | 3 | 2 | 2½ |
| | Engineering 3602, Thermodynamics | 3 | 2 | 2½ |
| | Engineering 3603, Fluid Properties and Mass Flow | 3 | 2 | 2½ |
| | Engineering 3247, Principles of Cost Control | 3 | 2 | 2½ |
| | Engineering 3405, Gage Laboratory (or Engineering 3404) | 1 | 0 | 2½ |
| | Electives | 3 | Arr. | Arr. |
| | Total | 19 | | |
| TERM 7 | Engineering 3604, Flow Processes and Energy Transfer | 3 | 2 | 2½ |
| | Engineering 3605, Heat Transfer | 3 | 2 | 2½ |
| | Engineering 3353, Design of Machine Members | 3 | 1 | 5 |
| | Engineering 1231, Engineering Materials Laboratory | 3 | 1 | 2½ |
| | Engineering 3263, Production Engineering | 3 | 1 | 5 |
| | Electives | 3 | Arr. | Arr. |
| | Total | 18 | | |
| TERM 8 | Engineering 3354, Design of Machines | 3 | 1 | 5 |
| | Engineering 4931, Electrical Engineering | 3 | 2 | 2½ |
| | Engineering 3264, Production Engineering | 3 | 1 | 5 |
| | Engineering 3606, Thermal Engineering Laboratory | 3 | 1 | 2½ |
| | Engineering 6112, Metallurgy of Casting, Working, and Welding | 2 | 2 | 0 |
| | Electives (including Engineering 3607 or 3608 or 3609) | 6 | Arr. | Arr. |
| | Total | 20 | | |
| TERM 9 | Project | 3 | Arr. | Arr. |
| | Engineering 4932, Electrical Engineering | 3 | 2 | 2½ |
| | Engineering 1154, Strength of Materials | 3 | 3 | 0 |
| | Electives | 11 | Arr. | Arr. |
| | Total | 20 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 10 | Project | 3 | Arr. | Arr. |
| | Engineering 4933, Electrical Engineering | 3 | 2 | 2½ |
| | Public Speaking 101 | 3 | 3 | 0 |
| | Engineering 3041, Nonresident Lectures | 1 | 1 | 0 |
| | Electives | 9 | Arr. | Arr. |
| | Total | 19 | | |
| | Total for ten terms | 180 | | |



# SCHOOL OF ELECTRICAL ENGINEERING

## FACILITIES

EARLY in 1955 the School of Electrical Engineering moved into Phillips Hall, a new building especially designed to house the School. Phillips Hall provides ideal instructional, administrative, and research facilities. The library, established through a generous gift from the McGraw-Hill Book Company in memory of the first director of the School, and known as the Alexander Gray Memorial Library, is housed in Sibley Dome as a part of the combined Mechanical, Electrical, and Civil Engineering Library.

Laboratory facilities include the electrical machinery laboratories, with a great variety of both direct- and alternating-current machinery; the electrical measurements and standardization laboratory, equipped for instruction in the checking of meters and secondary standards and in the precise measurements of electrical and magnetic quantities; the radio and communication laboratory, including microwave and ultra-high-frequency laboratories; the industrial electronics laboratory, for the study of electronic power and control devices; the electronics apparatus and project laboratory, for the construction of electronic apparatus by students according to their own designs; the vacuum tube laboratory, for the construction and testing of electron tubes; the servomechanism laboratory, for the study of closed loop control systems; the illumination laboratory; and the television and pulse technique laboratory.

In addition to these general laboratories, facilities available for instruction and research include the radio-astronomy laboratory, engaged primarily in basic research; the antenna laboratory, for the investigation of directional characteristics of antennas; the ionospheric laboratory; the high voltage research laboratory; the a-c network calculator, designed to study problems arising in complex electrical networks; and the fluid network analyzer, designed to solve problems of pressure and flow in fluid distribution systems by means of electrical analogies.

## CURRICULUM

The curriculum leading to the degree of Bachelor of Electrical Engineering is intended to create in the student an understanding of the meaning and the application of those laws of nature which are basic in the practice of electrical engineering and to develop a general knowl-

edge of the origins and the trends of modern society. Through the first eight terms, all students follow the same program of technical studies; in the last two terms interest in one or more of the subdivisions of electrical engineering may be developed. Courses in administration and the humanities are distributed throughout the curriculum in accordance with the student's increasing comprehension. In all, there are thirty-three hours of courses in the administrative field and the humanities in the curriculum. Of these, twenty-seven hours are specified, and six are elective. The student may substitute other courses in this category for fifteen of the twenty-seven specified. In addition to these thirty-three hours, there are twelve free electives that the student may take in the humanities if he so desires.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature for the second term of the introductory course in English.

The curriculum reflects the convictions of the Faculty that the modern engineer is fully equipped only if his traditional ability to manage devices and processes is accompanied by a knowedge of men and an awareness of their needs.

## INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program, providing periods of industrial experience interspersed among regular terms of study. The Program is described on pages 12–13.

## THE FRESHMAN YEAR

Since the curriculum of the freshman year in electrical engineering is essentially the same as the curricula in mechanical engineering and engineering physics, transfer of a student between any two of these curricula may occur before the third term without loss of time. The freshman curricula in civil engineering and in chemical and metallurgical engineering differ to such an extent from the curriculum in electrical engineering that a transfer into one of these curricula is almost certain to require a lengthening of the student's program.

## CLASS ADVISERS

An experienced member of the Faculty acts as Adviser to each new freshman class that enters the School of Electrical Engineering. With the sophomore year the class is assigned to another Adviser who generally continues to serve until the class graduates, counseling each student in regard to curriculum, registration, scholarship, and other matters of the academic program. In addition, he tries to be helpful in the solution of personal problems that the student may bring to him.

Because responsibility for approval of the registration of each student is vested in the Class Adviser, no cancellation of courses or other changes in program may be initiated without his knowledge and approval. If the student desires a program of courses which the Class Adviser does not approve, the student may seek approval of the program by petition to the Faculty of the School of Electrical Engineering.

## SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must either (1) pass the courses for which he is registered two weeks after the beginning of the term and have a weighted average grade of not less than 70%, or (2) if one course is failed or is canceled, the weighted average of the remaining courses must not be less than 75%. A student not meeting this requirement may be warned, placed on probation, or dropped from the School.

## ELECTIVE COURSES

The curriculum in electrical engineering allows each student to choose a considerable number of elective courses during the latter years of the curriculum. Some of the elective credit hours can be chosen without restriction, some must be nontechnical in the sense that they lie completely outside the field of engineering technology, and some must be either advanced courses in the sciences on which electrical engineering is based or in electrical engineering. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole tends to expand the student's mental horizon and to develop him as a well-rounded citizen.

The program of the fifth year includes two three-hour courses, designated as "Project." These are elective courses in the important respect that the student makes his own selection of the topic or problem which he will investigate under the general supervision of a Faculty member. It is expected that each student will choose a problem closely related to his major interest in electrical engineering.

Six elective credit hours must be selected from fields of study which develop an interest outside electrical engineering and its supporting sciences. The list of subjects that follows represents fields from which courses of the nontechnical category have been approved in the past. Other subjects may be approved upon petition.

| | | |
|---|---|---|
| Architecture | English | History |
| Astronomy | Entomology | Industrial and Labor Relations |
| Biology | Fine Arts | Journalism |
| Botany | Floriculture | Limnology |
| Dramatics | Geology | Literature |
| Economics | Government | Meteorology |

| | | |
|---|---|---|
| Modern Languages | Paleontology | Sociology |
| Music | Philosophy | Speech |
| Ornithology | Psychology | Zoology |

Nine elective credit hours must be selected from courses in electrical engineering, mathematics, or physics. At least one of the courses so selected must contain laboratory work. A course so selected must not contain a great amount of material that is essentially equivalent to that in required courses in the curriculum.

Acceptable courses are designated as follows:

1. Courses in electrical engineering numbered less than 4900.
2. Courses in mathematics numbered greater than 300.
3. Courses in physics numbered greater than 209, except 236.

The courses, elected in fulfillment of the nine-hour technical elective requirement, serve as a core for advanced studies in a particular phase of electrical engineering. Students may specialize in power systems and machinery, in industrial electronics and control, in radio and communications, in illumination, or in applied mathematics and physics. Alternatively, some students find it advisable to take advanced courses that lie in more than one of these specialties.

In addition to the fifteen elective hours enumerated above, there are twelve free electives. These may be chosen from among any courses in the University for which prerequisites are satisfied, including those in the foregoing list. By carefully planning the use of electives, students may carry out extensive programs of study in other divisions of the University during the fifth year of the curriculum.

In many cases students choose to combine all or some portion of the free-elective requirements with the technical-elective requirements in order to emphasize certain studies in electrical engineering. Some of the many fields of studies along with their related courses are listed below. These groupings of courses are not intended to imply that a student must confine his studies to any one field but are presented for general information.

COMMUNICATION CIRCUIT ANALYSIS AND NETWORKS

4511—Radio Communication Theory I
4563—Pulse Technique in Communication and Radar
4564—Transmission of Information
4571—Advanced Communication Networks

ELECTRIC POWER SYSTEMS

4351—Power Systems I
4352—Power Systems II
4353—Power Systems III
4371—High-Voltage Phenomena

## ELECTRON TUBES AND TRANSISTORS

4526—Design and Construction of Vacuum Tubes I
4527—Design and Construction of Vacuum Tubes II
4565—Electromagnetic Theory
4529—Transistors

## FEEDBACK CONTROL SYSTEMS

4711—Servomechanisms I
4712—Servomechanisms II
4810—Introduction to Electronic Computers
1175—Nonlinear Mechanics

## ILLUMINATION

4611—Introductory Illumination
4612—Illumination Engineering
4615—Illumination Seminar
Phys. 215—Physical Optics
Psych. 207—Perception

## INDUSTRIAL ELECTRONICS

4411—Electronic Control Equipment
4415—Advanced Electronic Controls
4421—Electronic Power Converters

## MATHEMATICS

611—Higher Calculus I
612—Higher Calculus II
613—Methods of Applied Mathematics I
614—Methods of Applied Mathematics II
621—Mathematical Methods in Physics I
622—Mathematical Methods in Physics II

## MICROWAVE RADIO ANTENNAS

4565—Electromagnetic Theory
4512—Radio Communication Theory II
4568—Antennas

## NUCLEAR POWER

8010—Nuclear Reactor Physics
—Nuclear Measurements
5505—Advanced Heat-Transfer and Diffusion
—Special Topics in Nuclear Power Engineering

PHYSICS

210—Advanced Laboratory
225—Electricity and Magnetism I
236—Electricity and Magnetism II
243—Atomic and Molecular Physics
254—Electronic Properties of Solids and Liquids

POWER MACHINERY

4321—Advanced Electrical Machine Theory
4326—Advanced Power Laboratory

RADIO ANTENNA COMMUNICATION SYSTEMS

4511—Radio Communication Theory
4531—Television Systems
4563—Pulse Technique in Communication and Radar
4551—Radio Aids to Navigation

RADIO AND COMMUNICATION

4511—Radio Communication Theory
4565—Electromagnetic Theory
4512—Radio Communication Theory II
4516—Radio and Communication Laboratory
4517—Radio and Communication Laboratory

RADIO WAVE PROPAGATION

4565—Electromagnetic Theory
4568—Antennas
4566—Radio Waves I
4567—Radio Waves II

Credit hours in advanced military science and tactics or air or naval science may be counted, to the extent of nine, toward the requirements of the baccalaureate degree. Six hours so credited are considered to lie within the free-elective area of the curriculum and three in the "non-technical" group.

*Combined Programs in Law and Business and Public Administration.* Students in the School of Electrical Engineering may apply for admission to special programs which will permit the completion of requirements for the B.E.E. degree in five years and the LL.B. in seven years or the M.B.A. or M.P.A. in six years. Such a program requires approval of the two schools involved and double registration in the fifth year. This results in reducing the time required for the second degree by a year.

*War Service Experience and Courses.* Provision is made for veterans to obtain some credit toward the baccalaureate degree for war service experience or courses. The student should consult his Class Adviser.

## CURRICULUM (B.E.E.)

| | | CREDIT HOURS | LEC. REC. HOURS | LAB. COMP. HOURS |
|---|---|---|---|---|
| TERM 1 | Mathematics 161, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 115, Mechanics | 3 | 3 | 2½ |
| | Chemistry 105, General Chemistry | 3 | 2 | 3 |
| | Engineering 3117, Descriptive Geometry | 2 | 0 | 5 |
| | Engineering 3402, Machine Tool Processes | 2 | 1 | 2½ |
| | (or Engineering 6110, Casting, Working, and Welding of Metals) | (2) | (1) | (2) |
| | English 111, Introductory Course | 3 | 3 | 0 |
| | Military Science and Tactics* | 2 | 2 | 1 |
| | Physical Education | 0 | – | 3 |
| | Total | 18 | | |
| TERM 2 | Mathematics 162, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 116, Heat, Sound, and Geometrical Optics | 3 | 3 | 2½ |
| | Chemistry 106, General Chemistry | 3 | 2 | 3 |
| | Engineering 3118, Mechanical Drafting | 2 | 0 | 5 |
| | Engineering 6110, Casting, Working, and Welding of Metals | 2 | 1 | 2 |
| | (or Engineering 3402, Machine Tool Processes) | (2) | (1) | (2½) |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Military Science and Tactics | 2 | 2 | 1 |
| | Physical Education | 0 | – | 3 |
| | Total | 18 | | |
| TERM 3 | Mathematics 163, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 117, Electricity and Magnetism | 3 | 3 | 2½ |
| | Engineering 1151, Mechanics | 3 | 3 | 0 |
| | Engineering 2131, Surveying | 1 | 0 | 2½ |
| | Engineering 3231, Accounting | 3 | 2 | 2½ |
| | Engineering 4110, Basic Electrical Engineering | 3 | 2 | 3 |
| | Military Science and Tactics | 2 | 2 | 1 |
| | Physical Education | 0 | – | 3 |
| | Total | 17 | | |

*The requirements in Military Training may be satisfied by a series of the four basic courses in any of the following: Military Science and Tactics, Air Science, Naval Science.

Class Advisers may permit substitution of a course from the approved nontechnical fields (page 41) for Engineering 3231.

| | | CREDIT HOURS | LEC. REC. HOURS | LAB. COMP. HOURS |
|---|---|---|---|---|
| TERM 4 | Mathematics 607, Applied Mathematics for Electrical Engineers | 3 | 3 | 0 |
| | Physics 118, Physical Optics and Atomic Physics | 3 | 3 | 2½ |
| | Engineering 1152, Mechanics | 3 | 3 | 0 |
| | Engineering 3530, Engineering Thermodynamics | 3 | 3 | 0 |
| | Engineering 4111, Basic Electrical Engineering | 3 | 2 | 3 |
| | Military Science and Tactics | 2 | 2 | 1 |
| | Physical Education | 0 | – | 3 |
| | Total | 17 | | |
| TERM 5 | Chemistry 401, Physical Chemistry | 3 | 3 | 0 |
| | A course in Economics | 3 | 3 | 0 |
| | Engineering 1153, Mechanics of Materials | 3 | 3 | 0 |
| | Engineering 4112, Alternating-Current Circuits | 3 | 2 | 3 |
| | Engineering 4116, Electric Circuit Laboratory | 3 | 1 | 3 |
| | History 165, Science in Western Civilization | 3 | 3 | 0 |
| | Total | 18 | | |
| TERM 6 | Engineering 1223, Engineering Materials | 3 | 3 | 0 |
| | Engineering 4113, Transmission Lines and Filters | 3 | 2 | 3 |
| | Engineering 4121, Electron Tubes and Circuits | 4 | 2 | 6 |
| | Engineering 4216, Electrical Machinery Laboratory | 4 | 2 | 3 |
| | History 166, Science in Western Civilization | 3 | 3 | 0 |
| | Total | 17 | | |

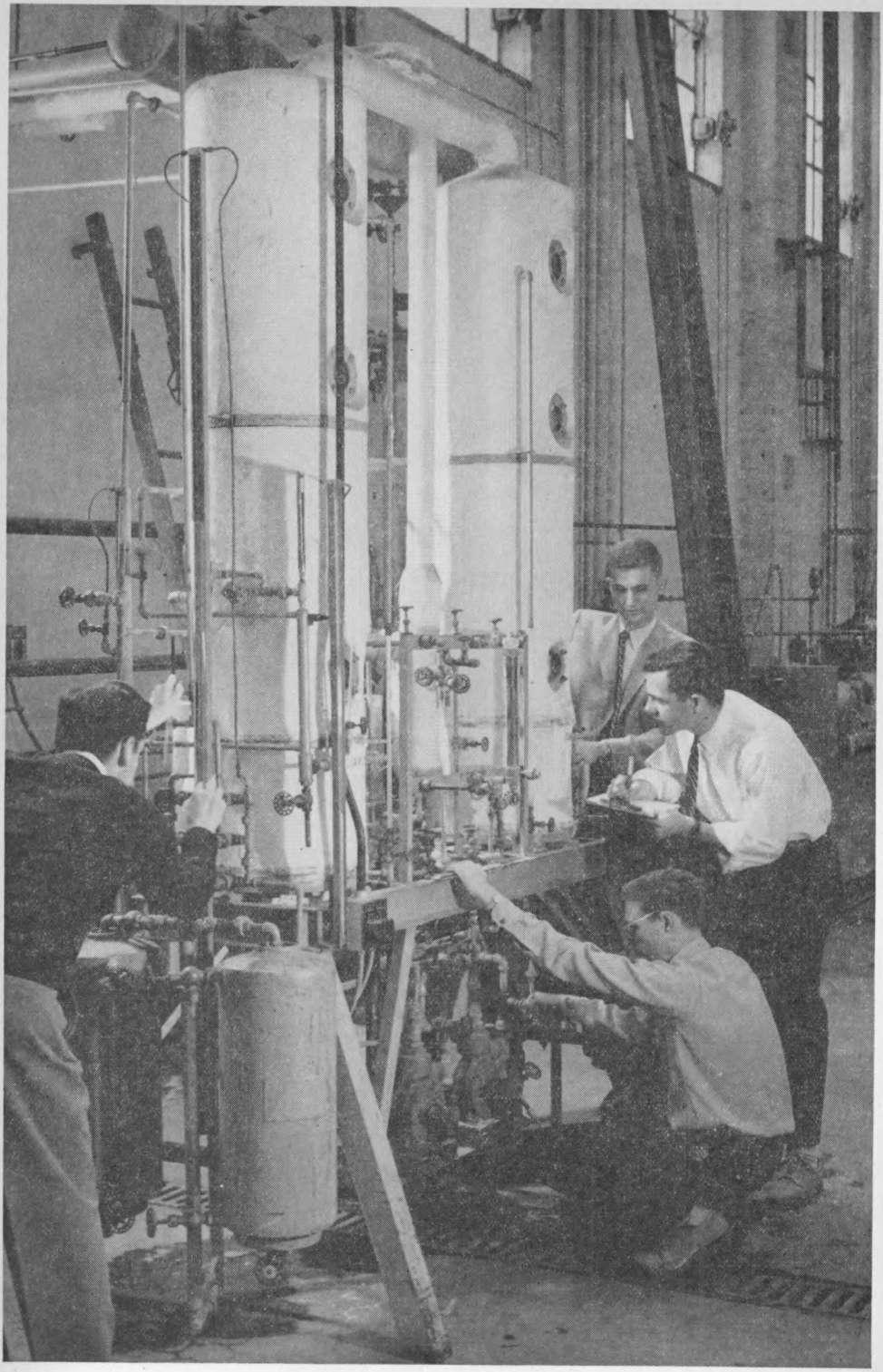
Class Advisers may permit substitution of courses from the approved nontechnical fields (page 41) for History 165 and History 166.

| | | | | |
|---|---|---|---|---|
| TERM 7 | Engineering 2331, Fluid Mechanics | 3 | 3 | 0 |
| | Engineering 4122, Electronic Circuit Elements | 4 | 3 | 3 |
| | Engineering 4221, Alternating Current Machinery | 4 | 2 | 3 |
| | Engineering 4114, Transients in Linear Systems | 3 | 2 | 3 |
| | Public Speaking 101 | 3 | 3 | 0 |
| | Total | 17 | | |
| TERM 8 | Physics 214, Atomic, Nuclear, and Electron Physics | 3 | 3 | 0 |
| | Engineering 3341, Machine Design | 4 | 3 | 2½ |
| | Engineering 4123, Electronic Circuit Elements | 4 | 3 | 3 |
| | Engineering 4226, Electrical Machinery Laboratory | 4 | 2 | 3 |
| | Psychology 101, Introduction to Psychology | 3 | 3 | 0 |
| | Total | 18 | | |

Class Advisers may permit substitution of a course from the approved nontechnical fields (page 41) for Psychology 101.

| | | CREDIT HOURS | LEC. REC. HOURS | LAB. COMP. HOURS |
|---|---|---|---|---|
| TERM 9 | Engineering Reports 4021 | 3 | 3 | 0 |
| | Free Electives | 6 | – | – |
| | Nontechnical Electives (see page 41) | 3 | – | – |
| | Senior Project 4091 | 3 | – | – |
| | Technical Electives (see page 42) | 3 | – | – |
| | Total | 18 | | |
| TERM 10 | Free Electives | 6 | – | – |
| | Nonresident Lectures | 1 | 1 | 0 |
| | Nontechnical Electives (see page 41) | 3 | – | – |
| | Senior Project 4092 | 3 | – | – |
| | Technical Electives (see page 42) | 6 | – | – |
| | Total | 19 | | |
| | Total for 10 Terms | 170 | | |
| | Plus Military Training | 8 | | |
| | GRAND TOTAL FOR 10 TERMS | 178 hours | | |

In addition to this, all students have to take Physical Education the first two years. All women students are excused from military training; male students may be excused for medical reasons.



# SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

## EQUIPMENT

THE SPECIALIZED training in chemical and metallurgical engineering is given in Olin Hall of Chemical Engineering and in the laboratories for foundry practice and metal working. The courses in chemistry are given in Baker Laboratory of Chemistry.

Olin Hall of Chemical Engineering was provided through the generosity of Franklin W. Olin as a memorial to his son Franklin W. Olin, Jr. This modern and well equipped building, with about 105,000 square feet of available floor space, provides lecture-room, recitation-room, and laboratory facilities for the instruction in chemical and metallurgical engineering. The unit operations laboratory, which is about one hundred feet long and fifty feet wide, extends through three floors and houses semi-plant-scale equipment for both instruction and research. It is served by a traveling crane and by its own shops and analytical laboratory. A considerable part of the building is subdivided into unit laboratories for advanced and graduate students.

## OUTLINE OF THE INSTRUCTION

The purpose of the instruction in this School is to train qualified young men for effective professional and administrative work in the chemical or the metallurgical industries. In the required curriculum some work in cultural subjects is included. By providing elective work in the later years the curriculum makes it possible for the student to take courses either in subjects outside the field of his major interest or in special or advanced technical subjects within that field.

The first four terms provide thorough training in chemistry, mathematics, and physics and the other basic subjects on which the specific professional training is based. The later terms include more strictly technical and more advanced courses in engineering and in chemistry and the fundamental courses in the specific fields of chemical and metallurgical engineering. The last two terms include the more advanced work in engineering and in the specialized fields. (For an outline of the course of study, see below.)

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in the second term.

## SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of 75 per cent, may be dropped or placed on probation.

If in the opinion of the Faculty of the School concerned, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course or from the University, at any time during the term.

Students who so desire may change from the curriculum in chemical engineering to that in metallurgical engineering, or from the curriculum in metallurgical engineering to that in chemical engineering, at any time before the beginning of the fifth semester without loss of time or credit.

## EMPLOYMENT AFTER GRADUATION

Graduates in chemical engineering find employment in the design, development, operation, and administration of chemical engineering plants. There is also some demand for men with chemical engineering training for technical sales work in the chemical industries and for editorial work on technical publications. Some graduates in chemical engineering continue their specialized training as graduate students in chemistry or chemical engineering to prepare for positions as research chemists or research engineers.

Graduates in metallurgical engineering are employed in the various industries engaged in the winning and refining of metals, in the foundry industry, and in industries in which the heat treatment, welding, and forming of metals are important. They have gone into research, development, production, and technical service, as well as graduate study.

## CURRICULUM (B.Ch.E.)

| | | | CONTACT HOURS | |
|---|---|---|---|---|
| | | CREDIT HOURS | LEC. REC. | LAB. COMP. |
| TERM 1 | Chemistry 111, Introductory Inorganic Chemistry | 3 | 3 | 0 |
| | Chemistry 115, Inorganic Chemistry Laboratory | 3 | 1 | 5 |
| | Physics 115, Mechanics | 3 | 3 | 2½ |
| | Mathematics 161, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | English 111, Introductory Course | 3 | 3 | 0 |
| | Engineering 3117, Drawing and Descriptive Geometry | 2 | 0 | 4 |
| | Total | 17 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 2 | Chemistry 112, Introductory Inorganic Chemistry | 3 | 3 | 0 |
| | Chemistry 116, Introductory Chemistry Laboratory | 3 | 0 | 6 |
| | Physics 116, Wave Motion, Sound, and Heat | 3 | 3 | 2½ |
| | Mathematics 162, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Engineering 3118, Drawing and Descriptive Geometry | 2 | 0 | 4 |
| | Total | 17 | | |

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

| | | | | |
|---|---|---|---|---|
| TERM 3 | Mathematics 163, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Chemistry 307, Introductory Organic Chemistry | 3 | 3 | 0 |
| | Chemistry 311, Organic Chemistry Laboratory | 2 | 0 | 6 |
| | Chemistry 224, Introductory Quantitative Analysis | 4 | 2 | 6 |
| | Engineering 5101, Introductory Chemical Engineering | 2 | 2 | 0 |
| | Physics 117, Electricity and Magnetism | 3 | 3 | 2½ |
| | Total | 17 | | |
| TERM 4 | Engineering 1156, Applied Mathematics | 3 | 3 | 0 |
| | Chemistry 308, Introductory Organic Chemistry | 3 | 3 | 0 |
| | Chemistry 312, Organic Chemistry Laboratory. | 2 | 0 | 6 |
| | Engineering 5102, Introductory Chemical Engineering | 2 | 2 | 0 |
| | Engineering 1151, Mechanics | 3 | 3 | 0 |
| | Physics 118, Physical Electronics and Optics | 3 | 3 | 2½ |
| | Public Speaking 101 | 3 | 3 | 0 |
| | Total | 19 | | |

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

| | | | | |
|---|---|---|---|---|
| TERM 5 | Chemistry 403, Introductory Physical Chemistry | 3 | 3 | 0 |
| | Chemistry 411, Physical Chemistry Laboratory | 2 | 0 | 5 |
| | Engineering 1152, Mechanics | 3 | 3 | 0 |
| | Engineering 5203, Chem. Eng. Technology | 2 | 2 | 0 |
| | Engineering 1255, Materials of Construction | 3 | 3 | 0 |
| | Engineering 5851, Chemical Microscopy | 3 or 0 | 1 | 5 |
| | Engineering 3253, Cost Accounting | 0 or 3 | 2 | 2½ |
| | Engineering 5303, Unit Operations of Chemical Engineering | 3 | 3 | 0 |
| | Total | 19 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 6 | Chemistry 404, Introductory Physical Chemistry | 3 | 3 | 0 |
| | Chemistry 412, Physical Chemistry Laboratory .. | 2 | 0 | 5 |
| | Engineering 1153, Strength of Materials ..... | 3 | 3 | 0 |
| | Engineering 5204, Chem. Eng. Technology .... | 2 | 2 | 0 |
| | Engineering 1256, Materials of Construction ... | 3 | 3 | 0 |
| | Engineering 3253, Cost Accounting ..... | 3 or 0 | 2 | 2½ |
| | Engineering 5851, Chemical Microscopy .....0 | or 3 | 1 | 5 |
| | Engineering 5304, Unit Operations of Chemical Engineering ..... | 3 | 3 | 0 |
| | Total ..... | 19 | | |
| TERM 7 | Engineering 5353, Unit Operations Laboratory | 3 | 2 | 3 |
| | History 165, Science in Western Civilization .... | 3 | 3 | 0 |
| | Engineering 1233, Materials Testing Laboratory | 3 | 1 | 2½ |
| | Engineering 5103, Chemical Engineering Thermodynamics ..... | 3 | 3 | 0 |
| | Engineering 5711, Library Use ..... | 1 | 1 | 0 |
| | Engineering 5745, Control of Engineering Processes ..... | 3 | 3 | 0 |
| | Electives ..... | 3 | – | – |
| | Total ..... | 19 | | |
| TERM 8 | Engineering 5354, Unit Operations Laboratory.. | 3 | 2 | 3 |
| | History 166, Science in Western Civilization .... | 3 | 3 | 0 |
| | Engineering 5104, Chemical Engineering Thermodynamics ..... | 3 | 3 | 0 |
| | Engineering 4931, Electrical Engineering ..... | 3 | 2 | 2½ |
| | Engineering 5701, Plant Inspections ..... | 1 | – | – |
| | Electives ..... | 6 | – | – |
| | Total ..... | 19 | | |
| TERM 9 | Engineering 4932, Electrical Engineering ..... | 3 | 2 | 2½ |
| | Engineering 5603, Chemical Equipment ..... | 2 | 2 | 0 |
| | Engineering 5605, Chemical Plant Design ..... | 2 | 1 | 3 |
| | Engineering 5503, Chemical Engineering Computations ..... | 2 | 2 | 0 |
| | Engineering 5953, Senior Project ..... | 2 | 0 | 6 |
| | Engineering 5746, Chemical Engineering Economics ..... | 3 | 3 | 0 |
| | Electives ..... | 3 | – | – |
| | Total ..... | 17 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 10 | Engineering 4933, Electrical Engineering | 3 | 2 | 2½ |
| | Engineering 5504, Chemical Engineering Computations | 2 | 2 | 0 |
| | Engineering 5604, Chemical Equipment | 2 | 2 | 0 |
| | Engineering 5606, Chemical Plant Design | 2 | 1 | 3 |
| | Engineering 5954, Senior Project | 2 | 0 | 6 |
| | Electives | 6 | – | – |
| | Total | 17 | | |

Elective courses may be taken in any college of the University. The selection must be approved by the student's Adviser.

## METALLURGICAL ENGINEERING CURRICULUM (B.Met.E.)

| | | | | |
|---|---|---|---|---|
| TERM 1 | Chemistry 111, Introductory Inorganic Chemistry | 3 | 3 | 0 |
| | Chemistry 115, Inorganic Chemistry Laboratory | 3 | 1 | 5 |
| | General Physics 115, Mechanics | 3 | 3 | 2½ |
| | Mathematics 161, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | English 111, Introductory Course | 3 | 3 | 0 |
| | Engineering 3117, Drawing and Descriptive Geometry | 2 | 0 | 4 |
| | Engineering 3403, Fundamentals of Machine Tools | 1 | 0 | 2½ |
| | Total | 18 | | |
| TERM 2 | Chemistry 112, Introductory Inorganic Chemistry | 3 | 3 | 0 |
| | Chemistry 116, Introductory Chemistry Laboratory | 3 | 0 | 6 |
| | General Physics 116, Wave Motion, Sound, and Heat | 3 | 3 | 2½ |
| | Mathematics 162, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Engineering 3118, Drawing and Descriptive Geometry | 2 | 0 | 4 |
| | Total | 17 | | |

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 3 | Chemistry 224, Introductory Quantitative Analysis | 4 | 2 | 6 |
| | Chemistry 301, Engineering Chemistry (Organic) | 2 | 2 | 0 |
| | General Physics 117, Electricity and Magnetism | 3 | 3 | 2½ |
| | Mathematics 163, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Geology 712, Metallurgical Raw Materials | 3 | 3 | 0 |
| | Engineering 6111, Introductory Metallurgy | 2 | 1 | 2 |
| | Total | 17 | | |
| TERM 4 | General Physics 118, Physical Electronics and Optics | 3 | 3 | 2½ |
| | Engineering 1156, Applied Mathematics | 3 | 3 | 0 |
| | Engineering 1151, Mechanics | 3 | 3 | 0 |
| | Engineering 3253, Cost Accounting | 3 | 2 | 2½ |
| | Elective | 3 | 3 | 0 |
| | Public Speaking 101 | 3 | 3 | 0 |
| | Total | 18 | | |

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

| | | | | |
|---|---|---|---|---|
| TERM 5 | Chemistry 403, Introductory Physical Chemistry | 3 | 3 | 0 |
| | Chemistry 411, Physical Chemistry Laboratory | 2 | 0 | 5 |
| | Engineering 1152, Mechanics | 3 | 3 | 0 |
| | Engineering 1255, Materials of Construction | 3 | 3 | 0 |
| | Engineering 5851, Chemical Microscopy | 3 | 1 | 5 |
| | Engineering 6501, Metallurgical Calculations | 2 | 2 | 0 |
| | Total | 16 | | |
| TERM 6 | Chemistry 404, Introductory Physical Chemistry | 3 | 3 | 0 |
| | Chemistry 411, Physical Chemistry Laboratory | 3 | 0 | 5 |
| | Engineering 1153, Strength of Materials | 3 | 3 | 0 |
| | Engineering 1233, Engineering Materials Laboratory | 3 | 1 | 2½ |
| | Engineering 1256, Materials of Construction | 3 | 3 | 0 |
| | Engineering 6811, Introductory Metallography | 3 | 1 | 5 |
| | Total | 17 | | |
| TERM 7 | Engineering 5103, Chemical Engineering Thermodynamics | 3 | 3 | 0 |
| | Engineering 5711, Library Use and Patents | 1 | 1 | 0 |
| | Engineering 6203, Smelting and Refining | 3 | 3 | 0 |
| | Engineering 6253, Unit Processes in Metallurgy | 3 | 1 | 2½ |
| | Engineering 6311, Physical Metallurgy | 2 | 2 | 0 |
| | Engineering 6351, Physical Metallurgy Laboratory | 3 | 1 | 5 |
| | Electives | 3 | | |
| | Total | 18 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 8 | Engineering 6114, Metallurgy of Casting, Working, and Welding | 3 | 2 | 2½ |
| | Engineering 6204, Smelting and Refining | 3 | 3 | 0 |
| | Engineering 6254, Unit Processes in Metallurgy | 3 | 1 | 2½ |
| | Engineering 6312, Physical Metallurgy | 2 | 2 | 0 |
| | Engineering 6701, Plant Inspections | 1 | 0 | 0 |
| | Engineering 4931, Electrical Engineering | 3 | 2 | 2½ |
| | Electives | 3 | 0 | 0 |
| | Total | 18 | | |
| TERM 9 | Engineering 5745, Control of Engineering Processes | 3 | 3 | 0 |
| | Engineering 6221, Advanced Process Metallurgy | 2 | 0 | 0 |
| | Engineering 6953, Senior Project | 2 | 0 | 6 |
| | Engineering 4932, Electrical Engineering | 3 | 2 | 2½ |
| | History 165, Science in Western Civilization | 3 | 3 | 0 |
| | Electives | 6 | – | – |
| | Total | 19 | | |
| TERM 10 | Engineering 6602, Metallurgical Design | 3 | 3 | 0 |
| | Engineering 6954, Senior Project | 2 | 0 | 6 |
| | Engineering 4933, Electrical Engineering | 3 | 2 | 2½ |
| | History 166, Science in Western Civilization | 3 | 0 | 0 |
| | Electives | 6 | | |
| | Total | 17 | | |

Elective courses may be taken in any college of the University. The selection must be approved by the student's Adviser.

## OPTIONS IN CHEMICAL AND METALLURGICAL ENGINEERING

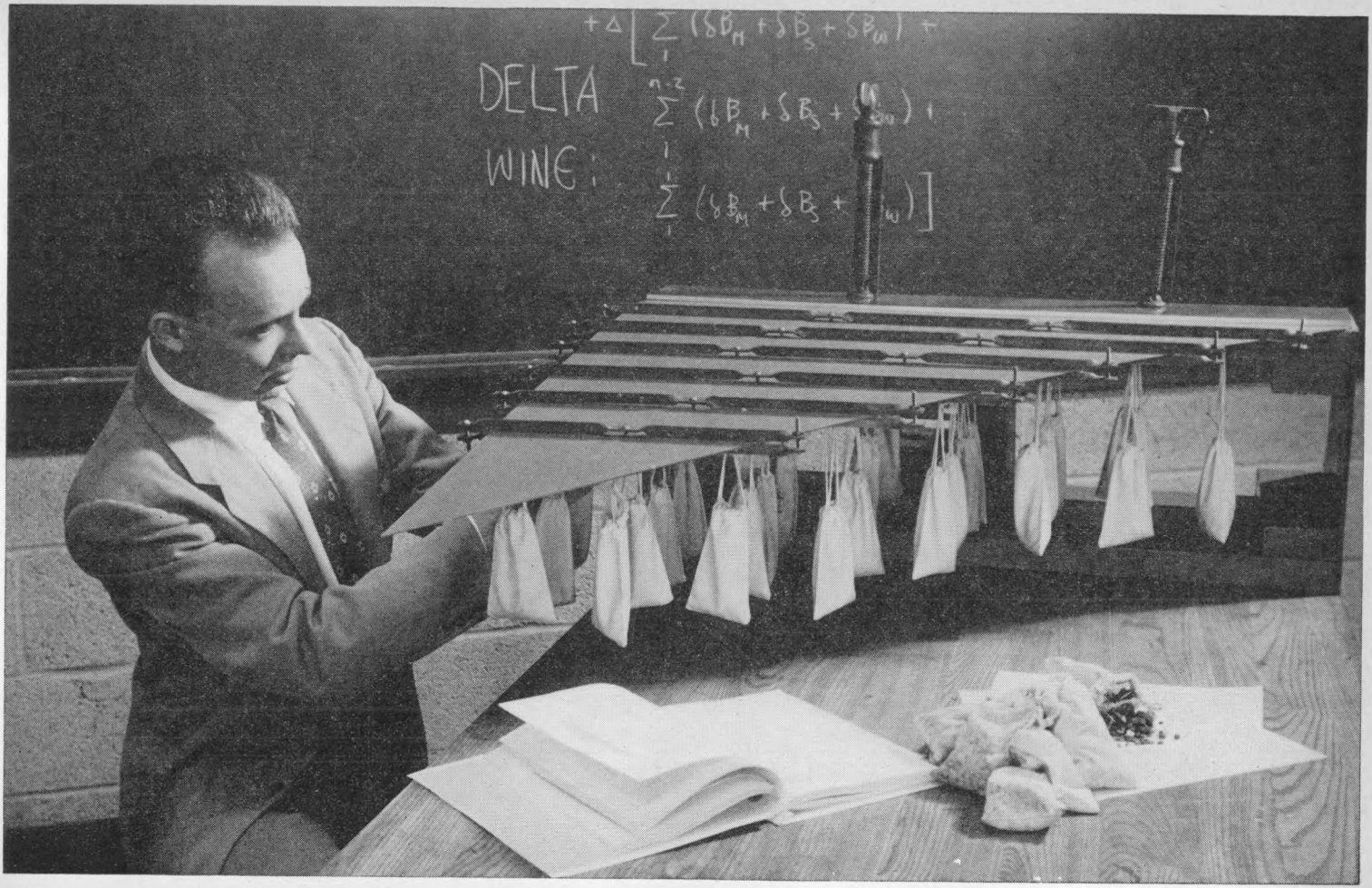
A student in chemical engineering or in metallurgical engineering may select his elective courses in any of several optional fields to provide somewhat more extensive training than is afforded by the required courses in the curriculum. The student may also, if he so desires, arrange his elective work to provide a cultural background broader than that given by the required courses. The selection of electives must be approved by the Class Adviser.

Those students in chemical or metallurgical engineering who are interested particularly in the financial and administrative aspects of engineering may register jointly in the School of Chemical and Metallurgical Engineering and in the Graduate School of Business and Public Administration at Cornell during their fourth and fifth years and may then, by continuing in the School of Business and Public Administration for one additional year after receiving the first degree

in engineering, be awarded the degree of Master of Business Administration or Master of Public Administration. In this way it is possible for a student to receive both the degree in engineering and the degree in business or public administration after a total period of residence of six years.

Students in chemical or metallurgical engineering who contemplate entering the legal profession may register jointly in the School of Chemical and Metallurgical Engineering and in the Law School of Cornell University in the fifth year of the course in chemical engineering and may count this year of work toward the degree of Bachelor of Laws as well as toward the degree in engineering.

Opportunities for summer employment in chemical and metallurgical industries are increasingly available to students who have completed two or more years of their training.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WING:

# THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

THE PRIMARY objective of this School is the training of selected engineering and science graduates in the scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out research and development engineering in the aeronautical and related industries and in aeronautical scientific institutions.

To this end, students are admitted to this School who have demonstrated, in their undergraduate careers, more than average abilities in analytical subjects, and who have shown adequate promise of carrying on graduate study successfully.

In the aeronautical engineering program, considerable emphasis is placed upon original research, both theoretical and experimental. Through the academic year, close contact is maintained between the Graduate School at the University and the Cornell Aeronautical Laboratory in Buffalo, N.Y. In addition, certain periods of employment at the Laboratory are offered to aeronautical engineering students—usually during their summer vacations. Students are urged to take advantage of such employment, if it is available. It is also possible that certain experimental equipment of the Laboratory will occasionally be available to graduate students in connection with their original research.

The Graduate School of Aeronautical Engineering is equipped with a fluid-mechanics laboratory on the campus in Ithaca for fundamental scientific research in fluid mechanics and aerodynamics.

## ADMISSION

Application for admission to the Graduate School of Aeronautical Engineering as a candidate for the degree M.Aero.E. should be made directly to the Director of the Graduate School of Aeronautical Engineering, College of Engineering, Cornell University. A special application blank for this purpose can be obtained from the office of the Director. It should be sent to the Director of the Graduate School of Aeronautical Engineering.

The degree M.Aero.E. is awarded under the jurisdiction of the College of Engineering, and therefore candidates for this degree do not register in the Graduate School of the University.

Students who desire to work for the degree Ph.D. with aeronautical engineering as their major subject must be admitted to the Graduate School of the University in the usual manner. They should make application to the Dean of the Graduate School, using the application blank for admission to the Graduate School.

## CURRICULUM

The aeronautical engineering curriculum is planned to accomplish the broad objectives stated above. Courses of study are provided leading to the degree of Master of Aeronautical Engineering and to the degree of Doctor of Philosophy with aeronautical engineering as the major subject.

*A. COURSE OF STUDY LEADING TO THE DEGREE M.AERO.E.* . . . This program of aeronautical engineering studies is not only applicable to much of the standard engineering work in the aeronautical industry, but beyond that the course is planned to increase the student's facility in the use of the basic sciences in aeronautical engineering and to stimulate growth in the performance of independent research and development work. Because the progress in this field is so extremely rapid, it is an essential objective of this program to go beyond the study of present-day practices and techniques and to prepare the student in the fundamental background and analytical methods that can be adapted to future development.

(1) *The curriculum requirement* for the degree M.Aero.E. is the successful passing of a series of courses or examinations in these subjects. The list of subjects reproduced below constitutes a standard of accomplishment for the M.Aero.E. candidate, but the Faculty will modify the list to suit the needs, interests, and background of each individual candidate. Sufficient course offerings are available to permit candidates to study in any of three areas of aeronautical engineering: (1) aerodynamics, (2) gasdynamics (aerophysics), (3) aeronautical structures. Active research in all three areas is being carried out in the School.

Although the standard list of required subjects is such as ordinarily to occupy (together with the thesis) four terms of graduate study, the residence requirement has been set at one year (two terms), so that students who enter the School with exceptional preparation, or are able otherwise to pass the required examinations, may be able to qualify for the degree in one year.

When the student desires to satisfy a requirement by examination (rather than by passing a course), he should request the Faculty of the School to schedule such an examination.

It is suggested that each candidate supplement his required program of courses, e.g., the standard list below, by additional courses either in aeronautical engineering or in other fields of study, so as to result in a balanced program of twelve to sixteen credit hours per term.

(2) *An acceptable Master's thesis,* based upon original research, is required of each candidate for the M.Aero.E.

(3) M.Aero.E. candidates must pass a *final examination,* either oral or both oral and written, administered by the Faculty of Aeronautical Engineering. The Faculty will frequently invite other members of the University staff to attend and to participate in such examinations.

## STANDARD LIST OF REQUIRED SUBJECTS FOR M.AERO.E.

| | CREDIT HOURS |
|---|---|
| Mathematics 611 and 612, Higher Calculus for Engineers and Physicists | 6 |
| or | |
| Engineering 1170 and 1171, Advanced Mechanics | 6 |
| Engineering 7101, Mechanics of Airplanes | 3 |
| Engineering 7102, Mechanics of Airplanes | 3 |
| or | |
| Engineering 7203, Aerodynamics of Power Plants | 3 |
| or | |
| Engineering 4991, Electronic Engineering | 3 |
| Engineering 7204, Gasdynamics | 4 |
| Engineering 7301, Theoretical Aerodynamics I | 3 |
| Engineering 7401, and 7402, Airplane Structures | 6 |
| Engineering 7403 and 7404, Airplane Design | 2 |
| Electives chosen from List A below | 12 |

## ELECTIVES: LIST A

| | |
|---|---|
| Engineering 7206, Special Topics in Physical Gasdynamics | 2 |
| Engineering 7302, Theoretical Aerodynamics II (Wing Theory) | 3 |
| Engineering 7303, Theoretical Aerodynamics III (Compressible Fluids) | 3 |
| Engineering 7304, Theoretical Aerodynamics IV (Viscous Fluids) | 3 |
| Engineering 7305, Aerodynamics of Compressible Viscous Fluids | 2 |
| Engineering 7306, Theory of Propellers and Rotors | 1 |
| Engineering 7405, Aero-Elastic Problems | 1 |
| Engineering 7406, Special Methods of Structural Analysis | 2 |
| Engineering 7407, Dynamics of Structures | 3 |
| Engineering 3566, Combustion Theory | 3 |
| Engineering 1162, Mechanics of Vibration | 3 |
| or | |
| Engineering 1170, 1171, Advanced Mechanics | 3, 3 |
| Engineering 1163, 1164, Applied Elasticity | 3, 3 |
| Engineering 1165, Theory of Elastic Stability | 3 |
| Engineering 1167, Theory of Plates and Shells | 3 |
| Engineering 1168, Anologies in Boundary Value Problems | 2 |
| Engineering 1175, Introduction to Nonlinear Mechanics | 3 |
| Engineering 1181, Current Literature in Applied Mechanics | 3 |
| Engineering 1261, Plastic Behavior of Solids | 3 |
| Mathematics 621, 2, Mathematical Methods in Physics | 4, 4 |
| Mathematics 641, 2, Partial Differential Equations | 3, 3 |
| Physics 242, Analytical Mechanics | 3 |
| Physics 243, Atomic and Molecular Physics | 3 |
| Physics 475, Theoretical Mechanics | 3 |
| Physics 090, Special Laboratory Work | (arranged) |

*B. COURSES LEADING TO THE DEGREE PH.D.* . . . Students will be admitted to candidacy for the degree Ph.D. as set forth in the current *Announcement of the Graduate School.* General requirements such as residence, major and minor subjects, requirements in foreign languages, qualifying examinations, and thesis are also explained there. Each candidate is required to complete a schedule of courses acceptable to his Special Committee, as explained in the Announcement.

## PREPARATION FOR GRADUATE STUDY

The Graduate School of Aeronautical Engineering will admit students holding baccalaureate degrees in any branch of engineering, physics, or mathematics, provided that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The courses of study in engineering physics and in mechanical engineering (Option A) are especially recommended to students who expect to enter this School after graduation.

It will be possible for Cornell students in the five-year undergraduate programs to complete the requirements for the degree M.Aero.E. in one year of graduate study instead of the normal two years, if they complete a sufficient number of the required graduate courses as electives in their undergraduate programs. The following courses are recommended for this purpose:

| | |
|---|---|
| Engineering 7101, 7102 | Mechanics of Airplanes |
| Engineering 7203 | Aerodynamics of Power Plants |
| Mathematics 611, 612 | Higher Calculus for Engineers and Physicists |
| or | |
| Mathematics 621, 622 | Mathematical Methods in Physics |
| Engineering 7204 | Gasdynamics |
| Engineering 7401, 7402 | Airplane Structures |
| Engineering 7403, 7404 | Airplane Design |
| Engineering 1170, 1171 | Advanced Mechanics |
| Engineering 1162 | Mechanics of Vibration |
| Engineering 1165 | Theory of Elastic Stability |
| Physics 242 | Analytical Mechanics |

To be admitted to graduate courses, an undergraduate student must

(1) be a regularly enrolled student in at least the seventh term of one of the engineering, physics, or mathematics curricula at Cornell University,

(2) show promise, by his previous scholastic record or otherwise, of ability satisfactorily to pursue advanced study and research, and

(3) have his admission to the courses recommended by the Director of the Graduate School of Aeronautical Engineering (or the chairman of the department concerned) and approved by the Dean of the College of Engineering.

It is further recommended that all students who expect to enter the Graduate School of Aeronautical Engineering include in their programs the following courses, or their equivalents:

| | |
|---|---|
| Mathematics 201 | Differential Equations |
| Engineering 1155 | Intermediate Mechanics |
| Engineering 1151, 1152, 1153 | Mechanics and Strength of Materials |
| Engineering 3530 | Thermodynamics |

# DEPARTMENT OF ENGINEERING PHYSICS

## OBJECTIVES

THE DEPARTMENT of Engineering Physics is a new department constituted so as to provide a type of education and training which will effectively bridge the gap between that of the basic sciences and that of conventional engineering practice. The general aim is to prepare students for a prospective career in technical research and advanced engineering development. As a result of the expanding technological activities in the country, the industrial research laboratories and engineering development laboratories are in urgent need of graduates with the vigorous and exacting course of study which the curriculum of this department provides.

## FACULTY

The administrative arrangement of the Department is such that the Faculty of the Department includes members of the science departments of the College of Arts and Sciences and members of the several Schools of Engineering in the College of Engineering who are particularly interested in the objectives of the Department.

## LABORATORY FACILITIES

The Department of Engineering Physics has a fully equipped laboratory of electron microscopy, including two large research type electron microscopes and equipment for research both on the instrument itself and on applications to problems in physics, chemistry, biology, and engineering materials. Facilities are also available for study in applied electron optics.

The Department also maintains a laboratory with much special equipment for the study of the elastic properties of single metal crystals, of elastometers, plastics, and similar materials, and of other phenomena related to the physics of the solid state.

In addition, students carrying out their project study have access to the other laboratories of the College of Engineering and to those of the College of Arts and Sciences as may be desirable.

## CURRICULUM

The curriculum leading to the degree of Bachelor of Engineering Physics covers intensive study over a five-year period. The course of

study is designed to combine the broad, basic, scientific and analytical training of the physicist with the knowledge of the properties of materials and the technological principles of the engineer. The subject matter falls into three main categories: fundamental science, namely, mathematics, physics, and chemistry; the properties and treatment of material; and engineering practice.

For training in engineering research and development, the student terminates the course by carrying out a semi-research project in a special field of his own choice, under the direction of a Faculty member who is an authority in the selected field. There are a great variety of these special fields in physical science and engineering. They include topics in electron physics, atomic and nuclear physics, physical optics, electron optics and applications including electron microscopy, X-rays and crystal structure, spectroscopy, engineering electronics, communications, electrical machinery, servomechanisms, ultra high-frequency generation and propagation, circuit analysis, elasticity and stress analyses, properties of materials, engineering mechanics, physical metallurgy, thermodynamics and heat transfer, aerodynamics, airplane structure, etc.

## ELECTIVE COURSES

*SCIENTIFIC AND TECHNICAL ELECTIVES* . . . Considerable flexibility in the technical courses is provided in the last few terms of the curriculum to allow the student to advance in some technical fields beyond the level provided by the required courses as his interest in such fields develops. To permit this, eighteen hours are provided to cover the semi-research project and the technical electives which may be selected, with the permission of the student's Adviser, from the following subjects: physics, mathematics, chemistry, physical metallurgy, advanced mechanics and elasticity, engineering materials, fluid mechanics, aerodynamics, heat power, communications, industrial electronics, servomechanism theory, ultra high frequency. The choice will depend largely on the student's particular ability or interest.

By suitable selection of technical electives during his last two years of candidacy for the B.Eng.Phys. degree, the qualified student may obtain an unusually sound and well rounded education preparing him for a career in one of the many specialized fields of engineering. Here are two examples.

*Aeronautical Engineering:* A properly qualified student may elect courses given in the Graduate School of Aeronautical Engineering and thus obtain an excellent preparation in aeronautical engineering at the undergraduate level. Also, this procedure will shorten the time required to complete the requirements for the M.Aero.E. degree if the student wishes to continue study in that field. Details of this arrangement are described on page 62.

*Nuclear Power:* It is possible to choose electives so as to provide a well rounded and extensive education for a career in the nuclear energy field or in nuclear reactor power developments. Courses in reactor physics, in nuclear measurements, in advanced heat transfer, and in physics of solids underlying radiation damage problems are available.

Members of the Faculty will assist the student in planning a special program in his particular field of interest.

*NONTECHNICAL ELECTIVES* . . . The curriculum provides for a minimum of thirty hours of liberal courses. Of these, twelve hours are specified as Introductory English and Modern Foreign Languages, and eighteen hours are to be chosen by the student in consultation with his Adviser.

These electives may be chosen from the following subjects: astronomy, biology, botany, the classics, economics, English, fine arts, government, history, industrial and labor relations, literature, music appreciation, philosophy, psychology, sociology, speech. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole assists in expanding the student's mental horizon and in developing him as a well-rounded citizen.

Students who pass the proficiency examination of the Department of Modern Languages and do not wish to continue the study of a language shall substitute six hours of other liberal electives in place of the language requirement. Students who wish to continue the modern language studied in high school may take the College Board Achievement Test in that language; otherwise, they will be asked to take a proficiency examination at the University. Further information is given in the section on "Proficiency Requirements" in the *Announcement of the College of Arts and Sciences.* Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

*ADDITIONAL ELECTIVES* . . . In addition, a maximum of nine hours of free electives is provided which may be chosen from any courses in the University which are open to the student, except, however, that not more than six credit hours toward the baccalaureate degree will be allowed in advanced military science and tactics or in naval science.

## CLASS ADVISERS

Members of each entering class in the engineering physics curriculum are assigned to an experienced Faculty member who will counsel and supervise each student in matters connected with choice of elective courses, registration, scholarship, and other matters of importance encountered during the student's entire college career. The personal

relationship between the Adviser and the student and the Adviser's intimate knowledge of the student's academic performance can be of great help to the student in obtaining the best results from his university training.

## SCHOLASTIC REQUIREMENTS

A student enrolled in the engineering physics curriculum is expected to maintain the following minimum scholastic requirements:

(1) receive a passing grade in every course for which he is registered,

(2) maintain each term a weighted average of at least 75%,

(3) exhibit natural aptitude and competence in the basic subject matter of the curriculum.

A student failing to satisfy these requirements may be put on probation or refused permission to continue his studies in the Department.

## THE ENGINEERING PHYSICS CURRICULUM

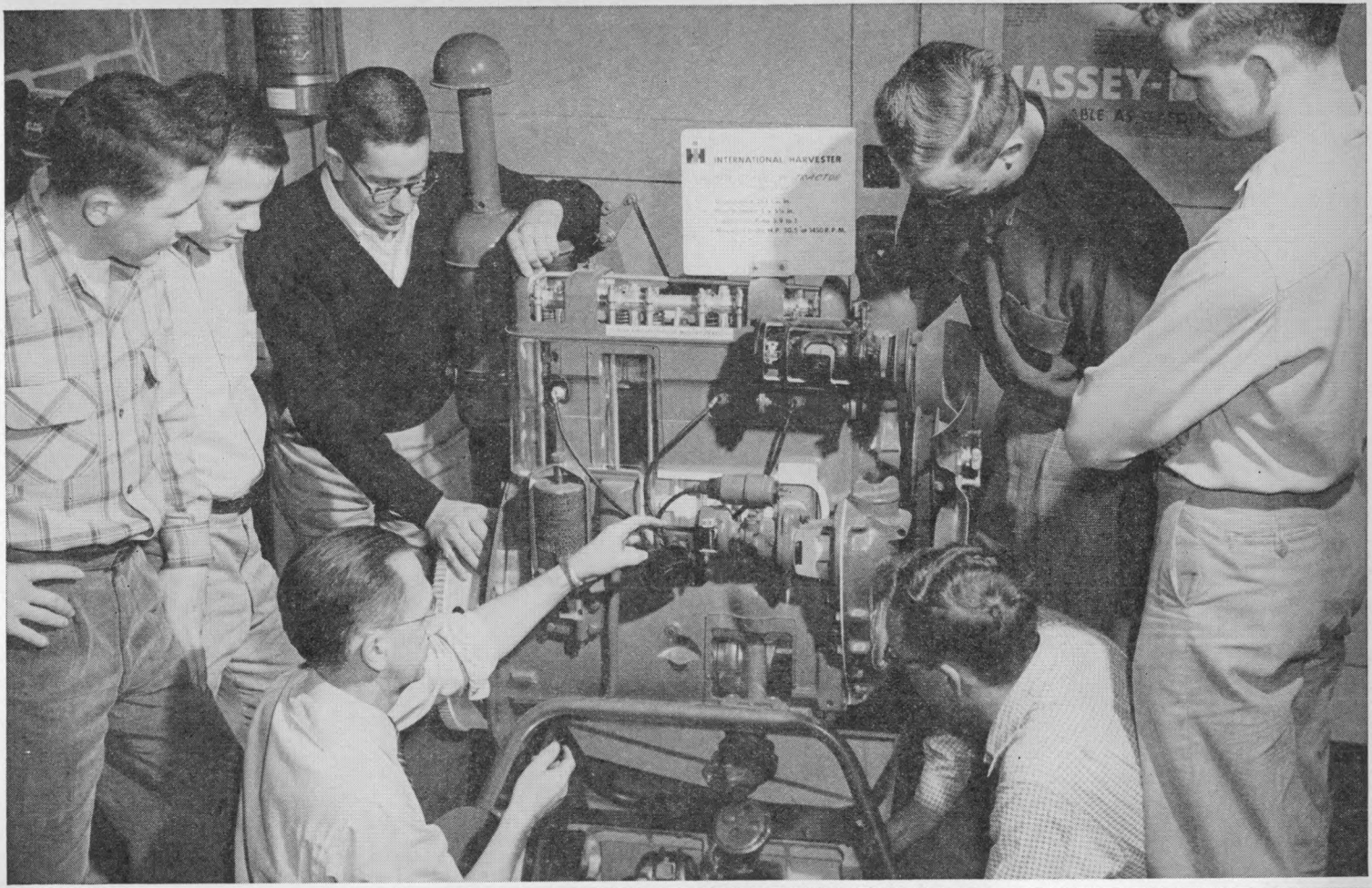
| | | CONTACT HOURS | | |
|---|---|---|---|---|
| | | CREDIT HOURS | LEC. REC. | LAB. COMP. |
| TERM 1 | Mathematics 161 or 181, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 115, Mechanics | 3 | 3 | 2½ |
| | Chemistry 105, General Chemistry | 3 | 3 | 2½ |
| | English 111, Introductory Course | 3 | 3 | 0 |
| | Engineering 3117, Drawing and Descriptive Geometry | 2 | 0 | 5 |
| | Liberal Elective | 3 | 3 | 0 |
| | Total | 17 | | |
| TERM 2 | Mathematics 162 or 182, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 116, Wave Motion, Sound, and Heat | 3 | 3 | 2½ |
| | Chemistry 106, General Chemistry | 3 | 2 | 3 |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Engineering 3118, Drawing and Descriptive Geometry | 2 | 0 | 5 |
| | Engineering 3403, Fundamentals of Machine Tools | 1 | 0 | 2½ |
| | Elective | 3 | | |
| | Total | 18 | | |
| TERM 3 | Mathematics 163 or 183, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 117, Electricity and Magnetism | 3 | 3 | 2½ |
| | Engineering 1151, Statics | 3 | 3 | 0 |
| | A modern foreign language | 6 | 2 | 6 |
| | Engineering 6110, Casting, Working and Welding of Metals | 2 | 1 | 2 |
| | Total | 17 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 4 | Mathematics 201, Elementary Differential Equations | 3 | 3 | 0 |
| | Physics 118, Electricity, Magnetism, and Light | 3 | 3 | 2½ |
| | Chemistry 402, Introduction to Physical Chemistry | 3 | 3 | 0 |
| | Physics 208, Physical Mechanics and Properties of Matter | 3 | 3 | 0 |
| | Engineering 4983, Basic Electrical Engineering. | 4 | 3 | 2½ |
| | Total | 16 | | |

In addition to these courses, students must satisfy the University's requirements in military training and physical education for the first four terms.

| | | | | |
|---|---|---|---|---|
| TERM 5 | Mathematics 613, Methods of Applied Mathematics | 3 | 3 | 0 |
| | Physics 225, Electricity and Magnetism | 3 | 3 | 0 |
| | Engineering 8121, Thermodynamics and Kinetic Theory | 3 | 3 | 0 |
| | Engineering 4116, Electric-Circuit Laboratory | 3 | 1 | 3 |
| | Engineering 1153, Mechanics of Materials | 3 | 2 | 2½ |
| | Elective | 3 | | |
| | Total | 18 | | |
| TERM 6 | Mathematics 614, Methods of Applied Mathematics | 3 | 3 | 0 |
| | Physics 242, Analytical Mechanics | 3 | 3 | 0 |
| | Engineering 8122, Thermodynamics and Kinetic Theory | 3 | 3 | 0 |
| | Engineering 4121, Electron Tubes and Circuits | 4 | 2 | 5 |
| | Elective | 3 | | |
| | Total | 16 | | |
| TERM 7 | Mathematics 615, Methods of Applied Mathematics | 3 | 3 | 0 |
| | Physics 243, Atomic and Molecular Physics | 3 | 3 | 0 |
| | Engineering 1201, Engineering Materials | 3 | 3 | 0 |
| | Engineering 4122, Electronic Circuit Elements | 4 | 2 | 5 |
| | Elective | 3 | | |
| | Total | 16 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 8 | Mathematics 616, Methods of Applied Mathematics | 3 | 3 | 0 |
| | Physics 254, Electronic Properties of Solids and Liquids | 3 | 3 | 0 |
| | Physics 210, Advanced Laboratory | 3 | 0 | 5 |
| | Engineering 1231, Engineering Materials Laboratory | 3 | 1 | 2½ |
| | Chemistry 416, Chemical Bonding and Physical Properties of Organic Molecules | 3 | 3 | 0 |
| | Elective | 3 | | |
| | Total | 18 | | |
| TERM 9 | Physics 210, Advanced Laboratory | 3 | 0 | 5 |
| | Engineering 1202, Advanced Materials | 3 | 3 | 0 |
| | Engineering 8051, Project | 3 | | |
| | Electives | 9 | | |
| | Total | 18 | | |
| TERM 10 | Physics 258, Mechanics of Continuum | 3 | 3 | 0 |
| | Engineering 8052, Project | 3 | | |
| | Electives | 12 | | |
| | Total | 18 | | |


INTERNATIONAL HARVESTER

# AGRICULTURAL ENGINEERING

A JOINT program administered by the Colleges of Agriculture and Engineering leads to the degree of Bachelor of Agricultural Engineering. Students in this curriculum register in the College of Agriculture during the first four years but take courses in the Colleges of Engineering, Arts and Sciences, and Agriculture. Registration for the fifth and final year is in the College of Engineering, which grants the degree.

## PURPOSES

The curriculum in professional agricultural engineering is to train engineers for agriculture in such fields as power and machinery, structures, electrification, soil and water management, and the processing and handling of farm products.

## OUTLINE OF INSTRUCTION

The curriculum leading to the degree of Bachelor of Agricultural Engineering requires five years of study. Subject matter is drawn from five basic fields of study:

1. Basic science (mathematics, chemistry, physics, biology, bacteriology, geology)
2. Engineering science (mechanics, property of materials, thermodynamics, heat transfer, electrical theory)
3. Engineering application (structural design, hydraulics, surveying, power, machinery design, water control and management)
4. Agriculture (soils, field crops, livestock feeding, farm management)
5. General studies (English, history, public speaking, economics)

Students in this curriculum are required to meet the farm-practice requirement of the College of Agriculture (see the *Announcement of the New York State College of Agriculture).*

## ADMISSION REQUIREMENTS

Requirements for entrance to this curriculum are the same as those for mechanical, civil, and electrical engineering. Since, however, it is the purpose of this curriculum to train engineers for agriculture, careful attention will be given to evidence of interest in and background for the work on the part of applicants.

## CURRICULUM (B.Agr.E.)

(For a complete description of the courses in agriculture, see the *Announcement of the New York State College of Agriculture.)*

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 1 | Mathematics 161, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 115, Mechanics | 3 | 3 | 2½ |
| | Chemistry 105, General Inorganic Chemistry | 3 | 2 | 3 |
| | English 111, Introductory course | 3 | 3 | 0 |
| | Engineering 3111, Drawing and Descriptive Geometry | 3 | 1 | 5 |
| | Agriculture 1, Orientation | 1 | 1 | 0 |
| | Total | 16 | | |
| TERM 2 | Mathematics 162, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 116, Wave Motion, Sound, and Heat | 3 | 3 | 2½ |
| | Chemistry 106, General Inorganic Chemistry | 3 | 2 | 3 |
| | English 112, Introductory Course | 3 | 3 | 0 |
| | Engineering 3112, Mechanical Drafting | 3 | 1 | 5 |
| | Agr. Engineering 2, Introduction to Agricultural Engineering | 2 | 2 | 0 |
| | Total | 17 | | |

In addition to taking these courses, all freshmen must satisfy the University requirements in physical education and in military training.

Farm practice is required. See the *Announcement of the New York State College of Agriculture.*

| | | | | |
|---|---|---|---|---|
| TERM 3 | Mathematics 163, Analytic Geometry and Calculus | 3 | 3 | 0 |
| | Physics 117, Electricity and Magnetism | 3 | 3 | 2½ |
| | Chemistry 301, Organic Chemistry | 2 | 2 | 0 |
| | Engineering 1151, Mechanics—Statics | 3 | 3 | 0 |
| | Biology 1, General Biology | 3 | 2 | 2½ |
| | Geology 115, Elementary Geology | 3 | 2 | 2½ |
| | Total | 17 | | |
| TERM 4 | Physics 118, Electronics and Optics | 3 | 3 | 2½ |
| | Chemistry 402, Physical Chemistry | 2 | 2 | 0 |
| | Engineering 1152, Mechanics—Dynamics | 3 | 3 | 0 |
| | Engineering 1153, Strength of Materials | 3 | 3 | 0 |
| | Engineering 2132, Surveying | 3 | 3 | 2½ |
| | Biology 1, General Biology | 3 | 2 | 2½ |
| | Total | 17 | | |

In addition to taking these courses, all sophomores must satisfy the University requirements in physical education and in military training.

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 5 | Engineering 1211, Materials of Construction | 3 | 2 | 2½ |
| | Engineering 2301, Elementary Fluid Mechanics | 3 | 3 | 0 |
| | Engineering 2731, Elements of Structural Engineering I | 3 | 2 | 2½ |
| | Agronomy 1, Nature and Properties of Soils | 5 | 5 | 2½ |
| | Engineering 1155, Applied Mathematics | 3 | 3 | 0 |
| | Total | 17 | | |
| TERM 6 | Engineering 3341, Machine Design | 4 | 3 | 2½ |
| | Engineering 1212, Materials of Construction | 3 | 2 | 2½ |
| | Engineering 2302, Applied Hydraulics and Hydrology | 3 | 2 | 2½ |
| | Agricultural Bacteriology 3 | 3 | 3 | 0 |
| | Agricultural Bacteriology Laboratory 5 | 1 | 0 | 4 |
| | Engineering 2732, Elements of Structural Engineering II | 3 | 2 | 2½ |
| | Total | 17 | | |
| TERM 7 | Engineering 2715, Reinforced Concrete Design | 3 | 2 | 2½ |
| | Engineering 3601, Thermodynamics | 3 | 2 | 2½ |
| | Agronomy 11, Production of Field Crops | 4 | 3 | 2½ |
| | Social Science Elective | 3 | 3 | 0 |
| | Animal Husbandry 10, Livestock Feeding | 4 | 3 | 2½ |
| | Total | 17 | | |
| TERM 8 | Engineering 3602, Engineering Thermodynamics | 3 | 2 | 2½ |
| | Agr. Engineering 221, Soils and Water Engineering | 3 | 2 | 2½ |
| | Agr. Economics 102, Farm Management | 5 | 3 | 3 |
| | Agr. Engineering 231, Farm Buildings Design | 3 | 2 | 2½ |
| | Social Science Elective (preferably Economics) | 3 | 3 | 0 |
| | Total | 17 | | |

Summer: six-week term. No. 206, Field Problems in Agricultural Engineering. Credit 6 hours.

| | | | | |
|---|---|---|---|---|
| TERM 9 | Engineering 3605, Heat Transfer | 3 | 2 | 2½ |
| | Engineering 4931, Electrical Engineering | 3 | 2 | 2½ |
| | Extension Teaching 101, Oral and Written Exp. | 2 | 2 | 0 |
| | Agr. Engineering 202, Farm Power | 3 | 2 | 2½ |
| | Agr. Engineering 252, Seminar | 1 | Arr. | Arr. |
| | Elective | 6 | Arr. | Arr. |
| | Total | 18 | | |

| | | CREDIT HOURS | CONTACT HOURS LEC. REC. | LAB. COMP. |
|---|---|---|---|---|
| TERM 10 | Engineering 3609, Refrigeration and Air Conditioning | 3 | 3 | 0 |
| | Engineering 4932, Electrical Engineering | 3 | 2 | 2½ |
| | Agr. Engineering 203, Agricultural Machinery Design | 3 | 2 | 2½ |
| | Agr. Engineering 252, Seminar | 1 | Arr. | Arr. |
| | Elective | 9 | Arr. | Arr. |
| | Total | 19 | | |
| | Total for Ten Terms | 178 | | |

# DESCRIPTION OF COURSES

THE COURSES listed in the preceding curricula are described in the following sections of this Announcement. Courses are described under the heading of the school or college in which the course is offered. Courses in chemistry, English, mathematics, physics, and certain courses in economics are offered by the College of Arts and Sciences. Courses in military training and physical education, under the direct supervision of the University as a whole, are listed in a general section.

The courses designated by four digit numbers are offered by the College of Engineering. The first digit represents the school or department. Descriptions of courses will be found in the section of this Announcement as follows:

1. Engineering Mechanics and Materials
2. Civil Engineering
3. Mechanical Engineering
4. Electrical Engineering
5. Chemical Engineering
6. Metallurgical Engineering
7. Aeronautical Engineering
8. Engineering Physics

General courses of instruction required by some or all of the schools within the College of Engineering but given in other colleges of the University are described on pages 111–118, inclusive.

For courses in other colleges not described here, to be taken as electives, see the Announcement of the appropriate college.

## ENGINEERING MECHANICS AND MATERIALS

Courses described in this section are given by the Department of Engineering Mechanics and Materials. They constitute a major part of the stem of basic engineering science prescribed for all engineering students and are directed toward the development of fundamental background for application to all phases of engineering work.

Advanced and graduate courses in these fields are also included in this section.

Messrs. CONWAY, CRANCH, CUYKENDALL, DIBBLE, GUNDER, HOWELL, JEFFREY, MASON, MOYNIHAN, PERKINS, SACK, SLATE, STEG, STUART, and WIEGANDT.

1134. *MECHANICS OF ENGINEERING—STRENGTH OF MATERIALS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1153. Elastic curves, safe loads, columns, flexure of beams. Problems showing the application of engineering design.

1145. *APPLIED ENGINEERING MATHEMATICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Mathematics 163 and Mechanics 1134. Elementary differential equations and their applications to engineering problems in the civil engineering fields.

1151. *MECHANICS OF ENGINEERING—STATICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Physics 115 and parallel registration in Mathematics 163. The principles of statics of particles, chains, and rigid bodies. Equilibrium, friction, centroids, moments and products of inertia, virtual displacements, graphical methods, three dimensional trusses and frames. Vector methods.

1152. *MECHANICS OF ENGINEERING—DYNAMICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1151 and 1155 or 1156, or parallel registration in Mathematics 607. The principles of dynamics of particles and rigid bodies. Rectilinear, curvilinear, rotational, and general plane motion of rigid bodies. Vector methods. (The section of this course for agricultural and civil engineering students is offered in the spring term only and does not require 1155 as a prerequisite.)

1153. *MECHANICS OF MATERIALS.* Credit 3 hours. 1 Lect. 2 Rec. Prereq., 1151. Stress and strain, tension, compression, and shear, riveted and welded joints, elementary beam theory, combined stresses, columns, strain energy, beams on several supports.

1154. *ADVANCED STRENGTH OF MATERIALS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1153 and 1155. Strength, stiffness and stability of machine parts, disks, plates, shells, thick cylinders, straight and curved beams; principal stresses in two and three dimensions; fatigue and theories of failure.

1155. *APPLIED ENGINEERING MATHEMATICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1151 and Mathematics 163. The formulation and solution of problems, arising in mechanical engineering, which involve the use of elementary differential equations and Fourier series. Emphasis is placed on numerical as well as analytical methods of solution.

1156. *APPLIED ENGINEERING MATHEMATICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Mathematics 163. The formulation and solution of problems in chemical engineering involving ordinary and partial differential equations, graphical and numerical methods, and special functions.

1159. *ADVANCED MECHANICS LABORATORY.* Credit 3 hrs. 2–2½ hour Lab. Primarily for graduate students. Analysis and design of experiments; measuring and loading techniques; SR-4 strain gages; vibration analysis of rods, plates and shells.

1162. *MECHANICS OF VIBRATION.* Credit 3 hrs. 3 Lect. Fall or spring as announced. For graduates and qualified undergraduates. Vibration of lumped and continuous systems; damping; free and forced motion; resonance; vibration isolation; self-excited vibration.

1163, 1164. *APPLIED ELASTICITY.* Continuing two terms. Credit 3 hrs. 3 Lect. For graduates and qualified undergraduates; spring and fall terms respectively. Three lectures per week each term. General analysis of stress and strain; Airey's stress function; Fourier and strain energy methods; torsion; thick cylinders; disks; beams on elastic foundations; curved bars; Castigliano's theorem.

1170. *ADVANCED MECHANICS.* Credit 3 hrs. Fall term. 3 Rec. Prereq., 1155. The formulation and solution of problems in engineering by vector methods, Lagrange's equations, generalized coordinates, Fourier series. Conservative systems.

1171. *ADVANCED MECHANICS.* Credit 3 hrs. Spring term. 3 Rec. Continuation of 1170. Nonconservative systems, energy methods, impact loads, operational methods.

1175. *INTRODUCTION TO NONLINEAR MECHANICS.* Credit 3 hrs. 3 Rec. Spring term. A study of the methods of analysis of the nonlinear electrical and mechanical systems frequently encountered in practice, including criteria for stability

and a comparison between linear and nonlinear methods. Emphasis will be placed upon the discussion of a number of problems rather than upon the coverage of a broad field.

1176. *INTRODUCTION TO NONLINEAR MECHANICS II.* Credit 3 hrs. Fall term. 3 Rec. Prereq., 1175, or permission of the instructor. Continuation of 1175. Nonlinear ordinary differential equations of second and higher order. Introduction to nonlinear partial differential equations. Examples are taken from electrical engineering and the mechanics of continua.

1198, 1199. *PROJECT.* Credit 3 hrs. each term. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering mechanics.

1172. *SELECTED TOPICS IN ENGINEERING MECHANICS.* Credit as arranged any term.

Theory of Elastic Stability
Theory of Plates and Shells
Rocket Theory and Design
Wave Propagation

1201. *ENGINEERING MATERIALS.* Credit 3 hrs. 3 Lect. Prereq., 1153 and Chemistry 402. A lecture course treating the physical and electrical properties of engineering materials with special emphasis on the relation of these properties to the structure of the materials and to their forming, working, heat treatment, etc.

1202. *ADVANCED ENGINEERING MATERIALS.* Credit 3 hrs. Fall term. Primarily for fifth-year students in engineering physics; others with consent of instructor. Discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semiconductors, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids; current literature is included in the assignments.

1211. *ENGINEERING MATERIALS.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 1153 and Chemistry 402. A study of the physical and mechanical properties of ferrous and nonferrous metals and alloys.

1212. *ENGINEERING MATERIALS.* Credit 3 hrs. 1 Rec. 2 Lab. Prereq., 1211. Should be preceded by or taken concurrently with 2715. A continuation of 1211 with special emphasis on timber, cement, concrete, and elemental concrete structural members.

1221. *ENGINEERING MATERIALS.* Credit 3 hrs. 3 Lect. 1 Rec. Prereq., 1153 and Chemistry 402 or its equivalent. A lecture course on the physical and mechanical properties of materials which govern their adaptability for specific service requirements. Following the development of the general principles involved, their specific application to iron and steel is examined and explained.

1222. *ENGINEERING MATERIALS.* Credit 3 hrs. 2 Lect. 1 Rec. Prereq., 1221 and Organic Chemistry 301 or their equivalent. A lecture course continuing the work of 1221 as applied to high alloy steels, cast irons, the nonferrous alloys and some nonmetallic materials. The effects of corrosion and temperature on the properties of materials are discussed.

1223. *ENGINEERING MATERIALS.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1153 and Chemistry 401. A study of the properties of ferrous and nonferrous metals and alloys, and nonmetallic materials such as cementing materials and concrete, plastics, wood, rubber, thermal and electrical insulating materials.

1231. *ENGINEERING MATERIALS LABORATORY.* Credit 3 hrs. 1 Lect. 1 Lab. Prereq., 1221 and 1153. Materials testing and the properties of metals and alloys. Tension, torsion, compression, bending, impact, fatigue, hardness, ductility, ferrous alloys, heat treatments, nonferrous alloys, metallography, radiography and magnaflux.

1232. *ENGINEERING MATERIALS LABORATORY.* Credit 3 hrs. 1 Lect. 1 Lab. Prereq., 1222 and 1231. Materials testing and the properties of the following nonmetallic materials: oils and lubricants, fuels, plastics, wood, cementing materials, and concrete.

1233. *ENGINEERING MATERIALS LABORATORY.* Credit 3 hrs. 1 Lect. 1 Lab. Prereq., 1255, 1256, and 1153. Materials testing and the properties of materials. Tension, torsion, bending, compression, impact, fatigue, creep and hardness; magnaflux and radiography; photoelasticity; lubricants; lubrication.

1252. *APPLICATIONS OF ENGINEERING MATERIALS.* Credit 3 hrs. 2 Lect. 1 Rec. Prereq., 1231. This course covers the applications of physical metallurgy to problems in engineering and processing operations, including casting, mechanical working and heat treatment, and the use of ferrous and nonferrous metals and alloys.

1255, 1256. *MATERIALS OF CONSTRUCTION.* Credit 3 hrs. each term. 3 Lect. Prereq. or parallel courses, Physical Chemistry 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

1298, 1299. *PROJECT.* Credit 3 hrs. each term. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering materials.

1272. *SELECTED TOPICS IN ENGINEERING MATERIALS.* Credit as arranged each term.

Engineering Materials Research
Advanced Concrete
Plastic Behavior of Solids
Structure and Properties of Matter
Physics of Engineering Materials

# CIVIL ENGINEERING

## DESCRIPTIVE GEOMETRY AND DRAWING

Mr. JENKINS and others.

2001. *DRAWING.* Credit 3 hrs. Fall. A first course of elementary civil engineering drawing, emphasizing the fundamentals of the graphic language as used in engineering. Technical lettering, the use of instruments, orthographic projection, freehand and technical sketching, working drawings, and charts and graphs. Prints are made of many of the tracings.

2002. *DRAWING.* Credit 3 hrs. Spring. Prereq., 2001 or equivalent. Instruction and drill in the fundamental conceptions of descriptive geometry dealing with the graphic solution of advanced space problems. This course develops a firm grasp of the principles of projection and provides ample training in visualization. Practical civil engineering problems from the fields of topographic mapping, structural drafting, and cartography are included in the course.

2004. *ADVANCED DRAWING.* Credit 1–3 hrs. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary drawings with artistic representations, so portrayed as to be readily intelligible to persons without technical training.

2005. *CARTOGRAPHY.* Credit 3 hrs. Fall. A study of the field of cartography, with particular attention to the principles of map projections, the conventions, scales,

and construction of planimetric, topographic, and chorographic maps from survey notes and data from aerial photographs. A first course to combine photogrammetry and topographic surveying into a practical course on map making and interpretation.

2006. *MAP REPRODUCTION.* Credit 3 hrs. Spring. The preparation of map manuscripts and models for reproduction by both photographic and mechanical methods of duplication. The selection, evaluation, and organization of cartographic material from ground and aerial surveys into map editions will assure the proper procedure to adopt for local circumstances.

## SURVEYING

Messrs. LYON, McNAIR, SPRY, and others.

2111. *ELEMENTARY SURVEYING.* Credit 2 hrs. Spring. 1 Rec. 1 Lab. Use and care of steel tape, level, and transit; note keeping; fundamental surveying methods; measurements of lines, angles, and differences of elevations; areas and plotting.

2112. *ADVANCED SURVEYING.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 2111. Elements of topographic, hydrographic, and geodetic surveying; map projections; elements of practical astronomy; city, land, and mine surveying; theory of errors; surveying specifications.

2113. *ROUTE AND AERIAL SURVEYING.* Credit 3 hrs. Spring. 1 Rec. 2 Lab. Prereq., 2112. Theory and practice in photogrammetric methods; theory and practice in staking out route locations involving simple, transition, and vertical curves; earthwork measurements and computations. About one-third of the course is devoted to photogrammetry, one third to paper reconnaissance, curve theory, and earthwork computations, and one-third to field work associated with route locations.

2114. *SUMMER SURVEY.* (Topographic, Hydrographic, Route, and Geodetic Survey Camp.) Credit 5 hrs. Field and office work six days a week for five weeks. Date to be announced in spring term. Prereq., 2113. Practical experience in surveying under field conditions. Extensive topographic survey and corresponding map with emphasis on transit-stadia and plane table-stadia methods. Hydrographic survey and map of Cayuta Lake. Complete route survey including reconnaissance from aerial photographs, preliminary survey, paper location, and staking of the final line. All horizontal and vertical control surveys are executed according to present standards, including base-line taping, triangulation with repeating and direction type optical-reading theodolites, subtense and trig traverse, precise leveling, and altimetry. Astronomic observations for azimuth and position are made and results computed.

2115. *LEAST SQUARES: ADJUSTMENT OF OBSERVATIONS.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Designed for students desiring to make experimental investigations. Studies are made of the principles of probability; precision of observations, the propagation of errors, and the application of the fundamental principles of least squares to typical surveying problems; criteria for determining the significance of results; and derivation of empirical formulas.

2117. *GEODETIC SURVEYING.* Credit 3 hrs. 3 Rec. Prereq., consent of instructor. Consideration of special problems in geodetic surveying; base line; triangulation; traverse; precise leveling; deflection of the plumb line; figure of the earth; determination of gravity; isostasy; magnetic properties of the earth. Subject to arrangement to meet the special needs of students.

2119. *MAP PROJECTIONS.* Credit 3 hrs. 1 Rec. 2 Lab. The theory of map projections. Construction of projections. Plane coordinate systems.

2120. *VERTICAL CONTROL.* Credit 3 hrs. Spring. Prereq., 2113. Lectures, reading, and field work. Principles of establishing a geodetic sea-level datum and of performing barometric, trigonometric, spirit, and electronic leveling. Study of precision altimetry by the single-base, two-base, and leapfrog methods. Determina-

tion of economic relationships of vertical control methods to mapping scale especially for photogrammetric mapping.

2121. *ELEMENTS OF PHOTOGRAMMETRY.* Credit 3 hrs. Fall. Prereq., 2113. Lectures, recitation, and laboratory work. Principles and practice of terrestrial and aerial photogrammetric mapping, including planning flights, control surveys, uncontrolled mosaics, radial-line control, simple stereo-plotting instruments, parallax distortions, graphical tilt determination, trimetrogen charting, and economics.

2122. *ADVANCED PHOTOGRAMMETRY.* Credit 3 hrs. Spring. Prereq., 2121. Lectures, reading, and laboratory work. An advanced study of photogrammetric principles including controlled mosaics, rectification, graphical, mechanical, and analytical space orientation. Readings and reports from current technical literature. The principles of many photogrammetric plotters are studied together with the economic relation of these instruments to density of field control, office methods, and personnel.

2123. *SURVEYING AND MAPPING INSTRUMENTATION.* Credit 3 hrs. Spring. Prereq., 2121. Lectures and assigned reading. Independent study of developments in surveying, mapping, and photogrammetric instruments including a brief historical sketch of instrumentation; optical-reading levels and transits; electronic base line measurement; precision altimeters; sonar equipment; equiangulator, odograph, and stereoscopic plotters. Correlation of the principles of new instruments and methods in this rapidly developing field.

2131. *ELEMENTS OF SURVEYING.* Credit 1 hr. 1 Lab. Fundamentals of engineering measurements. Appreciation of observations and errors. Principles of recording data. Use of steel tape, level, and transit. Problems of particular interest to students in fields other than civil engineering.

2132. *SURVEYING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Fundamentals of engineering measurements. Appreciation of methods of observations and errors. Principles of recording data. Use of steel tape, level, transit, and plane table. Aerial mapping. Emphasis on problems common in agricultural engineering.

2142. *GEODETIC OR PHOTOGRAMMETRIC ENGINEERING RESEARCH.* Prerequisites will depend upon the line of work to be pursued. Special problems in least squares, reduction of triangulation, and photogrammetric surveying as may be arranged.

2143. *SEMINAR IN GEODESY OR PHOTOGRAMMETRY.* Credit 1 to 6 hrs. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic or photogrammetric field.

## HYDRAULICS AND HYDRAULIC ENGINEERING

Messrs. BOGEMA, CHRISTENSEN, JORISSEN, PRIEST, and REID.

2301. *FLUID MECHANICS.* Credit 3 hrs. 3 Rec. Prereq., 1152. Fluid properties. Pressure and pressure intensity. Hydrostatics. Fluid flow concepts and basic equations. Dimensional analysis. Similitude. Laminar and turbulent flow. Flow in pipes. Flow in open channels. Flow around immersed bodies.

2302. *APPLIED HYDRAULICS AND HYDROLOGY.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 2301. Application of fluid mechanics principles to hydraulic problems. Flow measurement. Hydraulic machinery. Oil hydraulic systems. Elements of hydrology, including rainfall and runoff relations.

2303. *ADVANCED HYDRAULICS.* Credit 3 hrs. Fall. 3 Rec. Prereq., 2302 or 2331. This course involves more detailed and extended theory and application than the first course. Problems considered include stability of flotation, barometric leveling, fluids subject to acceleration, hydraulic similitude, water hammer, and open channel flow.

2304. *HYDRAULIC MEASUREMENTS.* Credit 3 hrs. Fall. 3 Rec. Prereq., 2302. The general flow equation. Volumetric and weight measurements. Pressure and pressure intensity. Measurements of fluid velocity. Rate of flow measurements in pipelines and open channels. Measurements under special conditions. Graphical and analytical methods of analyzing data. Errors and tolerances.

2305. *HYDRODYNAMICS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 2302 or 2331 and Differential Equations. Equations of motion for nonviscous liquids, force potentials, velocity potentials, conformal mapping, circulation, vortices, equations of motion for viscous liquids, boundary layer, separation, drag, turbulence, and wave motion.

2306. *PUMPS AND TURBINES.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 2302 or 2331. Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propeller type turbines; selection and testing of hydraulic machinery.

2307. *FLOW OF LIQUIDS IN OPEN CHANNELS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 2302. Uniform flow, rapidly varied flow, gradually varied flow, subcritical transitions, waves, supercritical transitions, bends, precipitous slopes, energy dissipation, and spillways.

2308. *HYDRAULIC MODELS.* Credit 3 hrs. Spring. 1 Rec. 2 Lab. Prereq., 2302. Theory of similitude and its application to models. Dimensional analysis, development of prediction equations, observations and measurements, theory of models, design and construction of models, distorted models, models of rivers, spillways, and outlet works.

2331. *FLUID MECHANICS.* Credit 3 hrs. 3 Rec. Prereq., 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulence, flow of compressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery.

2342. *HYDRAULICS RESEARCH.* Prereq., 2302 or equivalent. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is permissible and often desirable for two students to work together on the same investigation.

2343. *HYDRAULICS SEMINAR.* Credit 1–6 hrs. Abstraction and discussion of technical papers and publications in the hydraulics engineering field.

2403. *HYDRAULIC STRUCTURES.* Credit 3 hrs. Spring. 3 Rec. Prereq., 2412. Discussion of advanced problems related to hydraulic structures. Stress analysis in dams. Design of arch dams. Sedimentation. Spillways and river protection works. Channel transitions and controls. Hydraulics of locks.

2404. *WATER POWER.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 2302. Hydrologic and hydraulic investigation of water power sites; selection of turbines, power plant layout and equipment; economic considerations. Problems cover determination of available power, selection of turbines, use of pondage and storage, and determination of annual power output.

2411. *RIVERS AND HARBORS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 2302 and 2412. Rivers: regimen of flow in natural streams, flood waves, flood control, sedimentation, channel improvement, canalization, tidal effects, and ports. Harbors: gravity waves, shore improvement, harbor improvement, ports, and canals.

2412. *HYDRAULIC ENGINEERING.* Credit 3 hrs. 3 Rec. Prereq., 2302. Introduction to hydraulic engineering problems. Purpose, planning, and component parts of hydraulic projects. Flood routing. Ground water hydraulics. Reservoirs. Dams, spillways, and river protection works. Flumes and channels. Conduits, tunnels, penstocks. Locks. Hydraulic studies.

2442. *HYDRAULIC ENGINEERING RESEARCH.* Prereq., 2412 and one addi-

tional elective course in field of selected research. Subject and scope of investigation to be undertaken is selected by conference at beginning of term. Extraction of pertinent data from all available sources; construction and operation of hydraulic laboratory models.

2443. *HYDRAULIC ENGINEERING SEMINAR.* Credit 1–6 hrs. Discussion of selected topics in the hydraulic engineering field.

## SANITARY ENGINEERING

Messrs. GATES, GIFFT, and LYNCH.

2501. *MICROBIOLOGY IN ENGINEERING.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., Chemistry 106. Introduction to the nature, characteristics, and activities of microorganisms and their effect on man and his environment, including their roles in the transmission of disease, the cycles of nature, the decomposition of organic and inorganic material, and industrial applications and processes.

2502. *WATER SUPPLY AND TREATMENT.* Credit 3 hrs. 2 Rec. 1 Comp. Prereq., 2301, 2501. Sources of water supply, quantity available, uses, and rates of demand. Quality, examination, treatment, and purification. Collection, storage, pumping, and distribution systems. Laboratory periods include reports on water supply systems, design problems, and cost estimates.

2503. *SEWERAGE AND SEWAGE TREATMENT.* Credit 3 hrs. 2 Rec. 1 Comp. Prereq., 2301, 2501. The design of sanitary and storm sewers and the methods of treating sewage problems. The problems are largely of the nature of separate designs.

2504. *SANITARY BIOLOGY.* Required of graduate students who have not had 2501 or its equivalent. Credit 3 hrs. 2 Lect. 1 Lab. Special assignments. Either term. Fundamentals and methods of microbiology with emphasis on water bacteriology and aquatic biology. The nature and control of microorganisms associated with water quality and treatment and biology of self-purification and of waste treatment processes.

2506. *ADVANCED WATER SUPPLY.* Credit 3 hrs. Spring. Prereq., 2502. General principles and methods involved in furnishing safe water supplies of satisfactory quality. Water treatment methods, and design and operation of water treatment plants.

2507. *ADVANCED WASTES TREATMENT.* Credit 3 hrs. Fall. Prereq., 2503. Principles involved in the design, construction, and operation of sewage treatment works, including reference to existing typical plants. The disposal of sewage by dilution; stream pollution and self-purification; sewage treatment methods.

2508. *INDUSTRIAL WASTES.* Credit 3 hrs. Fall. Prereq., 2503. The treatment of industrial wastes, such as wastes from tanneries, packing houses, mines, canning factories, textile mills, paper and pulp mills, creameries, cheese factories, condenseries, breweries, sugar refineries, etc. Numerous references, bulletins, reports.

2509. *PUBLIC HEALTH AND COMMUNITY SANITATION.* Credit 3 hrs. Spring. 3 Rec. A general course outlining principles of communicable disease control; organization of health departments; environmental sanitation, water supply, waste disposal, milk, food sanitation; insect and rodent control; industrial hygiene; vital statistics. Course adjusted to the needs of the students enrolled.

2511. *SANITARY ENGINEERING LABORATORY.* Credit 3 hrs. 1 Rec. 2 Lab. Prereq., 2502, 2503. The application of physical, chemical, and bacteriological principles, methods, and procedures to the analysis and treatment of water, sewage, and industrial wastes. Laboratory scale study of water and sewage treatment processes.

2532. *MUNICIPAL SANITATION.* For students not in Civil Engineering. Credit 3 hrs. Fall. Lectures, reports, field trips. The principles of water supply, disposal of wastes, and community sanitation as related to municipal and regional problems,

from the standpoint both of planning and operation. Economic and legal problems in connection with industrial wastes and stream pollution control programs.

2541. *PROJECT.* Credit 3 hrs. Should be preceded by 2502 and 2503 or equivalent courses. Problems may be elected such as the design of sewerage systems, or treatment plants for municipal sewage, industrial waste, or industrial or municipal water supply.

2542. *SANITARY ENGINEERING RESEARCH.* Prerequisites will depend upon the particular problem to be pursued, but in general they should include work in water analysis and bacteriology, and courses in hydraulics and sanitary engineering dealing with the field in which the work is to be undertaken. Hours, credit for work, variable.

2543. *SANITARY ENGINEERING SEMINAR.* Open to specially selected seniors or graduate students. Credit 1–6 hrs. Abstraction and discussion of technical papers and publications in the sanitary field.

## TRANSPORTATION ENGINEERING

Messrs. BELCHER, HEWITT, and LEWIS.

2602. *TRANSPORTATION.* Credit 3 hrs. 3 Rec. Prereq., Economics 105 or consent of the instructor. The historical, economic, regulatory, construction, and operational aspects of transportation. Designed particularly for engineering students.

2610. *HIGHWAY ENGINEERING.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2113, and preceded by or taken concurrently with 2725. Highway administration, planning, economy, and finance; location (aerial photo methods included); elements of geometric design, intersections; traffic engineering; drainage; highway materials and soils; subgrade structure; base courses; design and construction of flexible and rigid pavements.

2612. *HIGHWAY LABORATORY—BITUMINOUS.* Credit 3 hrs. Spring. Prereq., 2610, or may be taken concurrently with 2610. Bituminous materials are tested and aggregates studied for their compatibility with bitumens. Mixes are designed and tested for stability. Condition surveys are made on various classes of bituminous pavements. Laboratory fully equipped for all phases of applied and research studies.

2613. *HIGHWAY LABORATORY—STABILIZATION.* Credit 3 hrs. Fall. 2 Lab. 1 Seminar. Prereq., 2725 and 2610, or may be taken concurrently with 2610. Evaluation of current soil stabilization practices. Correlation of field and laboratory compaction procedures. Freeze-thaw and strength tests on soil samples stabilized with bituminous materials, Portland cement, and chemicals. Condition surveys are made on stabilized roads. Laboratory fully equipped for all phases of applied and research studies.

2614. *HIGHWAY DESIGN—STRUCTURAL.* Credit 3 hrs. Fall. 3 Rec. Prereq., 2610, or consent of the instructor. Part I: Soil index properties and highway soil classification systems; surveying and sampling; subgrade evaluation, including field and laboratory CBR; subgrade modulus; compaction, drainage, and frost action; stabilization; aggregates. Part II: Design and construction of base and surface courses for flexible pavements. Part III: Design and construction of rigid pavements.

2615. *HIGHWAY DESIGN—GEOMETRIC.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 2610, or consent of the instructor. Route selection; design controls and criteria, including vehicle characteristics and highway capacity; sight distance, and horizontal and vertical control; cross section elements; right-of-way problems and access control; at-grade intersection design, including rotary and channelized intersection; grade separations and interchanges; regional systems of highways, freeways, and parkways.

2617. *AIRPORT ENGINEERING.* Credit 3 hrs. Spring. 2 Rec. and 1 Lab. Prereq.,

2610, 2725. Airport administration, planning, and design. Site selection—size and location; design standards; airport layout—runway patterns and orientation; flexible and rigid pavement design; drainage, gradings; marking and lighting.

2618. *LOW-COST ROADS.* Primarily for foreign students. Credit 3 hrs. Prereq., 2610 or its equivalent. Study of economic importance of routes and selection of roads (farm-to-market) to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials; drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low-cost roads.

2619. *TRAFFIC ENGINEERING—OPERATIONS.* Credit 3 hrs. 2 Lab. 1 Seminar. Prereq., preceded by or taken concurrently with 2620. Definition of traffic problems; collection of field data; analysis of field data; findings, conclusions, and recommendations. Traffic surveys. Design of traffic control systems.

2620. *TRAFFIC ENGINEERING.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 2610. City and highway traffic surveys and designs. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting, traffic control and routing. Signs, signals, and markings. Urban traffic consideration in city planning. Driver reactions and habit pattern. Traffic engineering organization.

2621. *ANALYSIS AND INTERPRETATION OF AERIAL PHOTOGRAPHS.* Preregistration required. Credit 3 hrs. 2 Lect. 1 Lab. (The student is expected to pay the cost of field trips and aerial photographs for use in a term project which amounts to approximately $10.) A study of the soil and rock areas of the United States and the patterns present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Field training in selected test areas. Emphasis is placed on interpretation for engineering, regional planning, and agricultural purposes.

2622. *ADVANCED INTERPRETATION OF AERIAL PHOTOGRAPHS.* Preregistration required. Credit 3 hrs. Organization of course depends upon fields of interest. Special problems: four each on ground water, engineering projects, agricultural soils mapping, and irrigation.

2641. *PROJECT, TRANSPORTATION ENGINEERING.* Credit 3 hrs. Projects in the various fields of transportation, advanced aerial photographic studies, and traffic engineering may be developed by conference between professors and students. Projects may involve integrated planning or design drawing upon several fields of interest, or they may concentrate upon special subjects. Adequate facilities, material, and sources of data are necessary to a satisfactory project.

2642. *TRANSPORTATION ENGINEERING RESEARCH.* Students who wish to pursue one particular branch of transportation engineering further than can be done in any of the regular courses may elect work in this field. The work may be in the nature of an investigation of existing methods or systems, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2643. *TRANSPORTATION ENGINEERING SEMINAR.* Credit 6 hrs. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the transportation engineering field.

## STRUCTURAL ENGINEERING

Messrs. BIJLAARD, BRUNGRABER, FISHER, GURALNICK, HOUGH, MASON, McGUIRE, and WINTER.

2701. *ELEMENTARY STRUCTURAL ANALYSIS.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 1153. A first course in structural theory. Determination of reactions and

internal forces and moments in beams, girders, trusses, simple frames, and three-hinged arches due to stationary and moving loads. Use is made of graphical and analytical methods and of influence lines.

2702. *STEEL AND TIMBER STRUCTURES.* Credit 3 hrs. 3 Lab. Prereq., 2701. Analysis and design of steel members and connections. Design of welded and riveted roof trusses. Design of steel railway girder bridge. Characteristics, properties, and mechanics of timber. Partial design of segmental-member timber-roof truss.

2704. *STATICALLY INDETERMINATE STRUCTURES.* Credit 3 hrs. 3 Lect. Prereq., 2702. Deflections. Classical and modern methods of analysis of statically indeterminate beams, frames, trusses. Methods of analysis. Influence lines. Members of varying cross section.

2706. *ADVANCED STEEL DESIGN.* Credit 3 hrs. 3 Lab. Prereq., 2713 or the equivalent. Critical study of current specifications for the design of steel buildings. Study of steel framing systems in current use. Problems in the analysis and design of commercial and industrial buildings.

2709. *ADVANCED STRUCTURAL ANALYSIS.* Credit 3 hrs. 3 Rec. Prereq., 2704 or equivalent. Review of fundamental methods for solving indeterminate structures and extension to more involved problems. Curved beams, arches, rings, space frames. Numerical methods, limit analysis, model analysis.

2710. *STRENGTH OF STRUCTURES.* Credit 3 hrs. 3 Rec. Prereq., 2704; can be taken concurrently. Analysis of two- and three-dimensional stress and strain. Theories of failure of ductile and brittle materials. Strain energy methods applied to bending, shear, buckling, and impact. Structural materials under load, strain hardening, residual stresses, hysteresis, stress concentration, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Plastic or ultimate design of steel and reinforced concrete structures. Critical discussion of current design specifications.

2711. *BUCKLING OF STRUCTURES.* Credit 3 hrs. 3 Rec. Prereq., 2710 and 1145 or equivalent. Analysis of elastic and plastic stability. Determination of buckling loads and maximum stresses of columns with and without initial crookedness and eccentricity. Solid and open web columns with variable cross-section. Beam columns. Lateral strength of unbraced beams. Buckling loads and ultimate strength of thin, compressed plates. Design of thin-walled steel structures. Critical discussion of current design specification.

2713. *STRUCTURAL DESIGN.* Credit 3 hrs. 3 Lab. Prereq., 2702, 2704, 2715, 2720. Primarily a project course. Discussion of fatigue, limit design, light gage steel design. Design of a highway truss bridge. Planning and design of representative portions of a complete structural project (building, bridge, or other structure.) Integrated use of procedures presented in other courses.

2715. *REINFORCED CONCRETE DESIGN.* Credit 3 hrs. 3 Lab. Prereq., 2704; can be taken concurrently. A first course in reinforced concrete. Elementary theory of reinforced concrete applied to rectangular slabs, T-beams, beams reinforced for compression, columns, and footings. Shear, diagonal tension, and direct stress combined with flexure. Several design reports which include reinforcement drawings, schedules, and formwork.

2716. *ADVANCED REINFORCED CONCRETE DESIGN.* Credit 3 hrs. 3 Lab. Prereq., 2715 or equivalent. Study of current specifications for the design of concrete structures. Study of concrete building framing systems in current use. Yield line theory. Representative design problems, e.g., flat slab building, highway bridge, arch.

2717. *BRIDGE DESIGN.* Credit 3 hrs. Prereq., 2704, 2715. Design of more complex types of steel and concrete bridges, such as continuous truss, multiple box culvert, rigid frame, arch. Basic planning of bridge project and study of problems common to all types of bridges, including substructures. Attention is given to traffic,

hydraulic, and economic requirements, and use of field data, preliminary surveys, and model studies.

2718. *PRESTRESSED CONCRETE.* Credit 2 hrs. Properties of material used in prestressed concrete. Creep of concrete. Prestressing methods. Design of statically determinate prestressed members. Ultimate strength and factors of safety. Discussion of statically indeterminate systems. Application of prestressing to complete structures.

2719. *ENGINEERING PLASTICITY.* Credit 2 hrs. 2 Rec. Prereq., 2710 and 1145 or equivalent. Plastic behavior as based on crystalline structure. Brittle v. plastic behavior. Mechanism of plastic deformation and plasticity condition. Flow lines. Application to strength of metal structures and geophysics. Plastic buckling of columns and plates.

2720. *FOUNDATIONS.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2715, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinnings. Design problems. Introduction to geophysical exploration.

2725. *ELEMENTS OF SOILS ENGINEERING.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., Geology 113, 1153, 2301. Formation and composition of soil, its properties, and its behavior as an engineering material. Principles of soil identification and classification, terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with applications to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Lateral earth pressure. Soil exploration. Laboratory tests for experimental determination of above mentioned soil characteristics and evaluations and use of data.

2726. *SOILS ENGINEERING THEORY.* Credit 3 hrs. Fall. 3 Lect. Prereq., 2725. Principles of mechanics and strength of materials relating to typical soils engineering problems and the fundamental physical and chemical characteristics of soil which affect their application. Methods for determining the distribution of stresses in semi-infinite soil masses, stress at a point, and the Mohr theory of rupture. Composition, structure, and stress-strain characteristics of soil. Calculation of settlement of structures, the stability of earth slopes and of embankment foundations. Basic principles of flow of water through soil, flow net construction, rate and effect of seepage. Lateral earth pressure theory.

2727. *APPLIED SOILS ENGINEERING.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 2726. Application of soils engineering theory of problems. Planning and conducting of subsurface investigations, determination of significant physical and chemical soil characteristics by test or other means, including appropriate laboratory exercises, analysis of actual designs of proposed structures for prediction of settlement, stability, rate of seepage, or other service requirements, methods of inspection and control of earthworks construction, selection and placement of materials, compaction and stabilization.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING I.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1151, 1153. Analysis of statically determinate and simple statically indeterminate structures. Determination of reactions and internal forces and moments caused by stationary loads, by means of analytical and graphical methods.

2732. *ELEMENTS OF STRUCTURAL ENGINEERING II.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2731. Design of simple steel and timber structures. Analysis and design of members and connections, roof trusses, floor systems, and other structures.

2741. *PROJECT.* Prereq., 2702, 2703 and 2715. The student may select a design problem such as the following: (a) an arch bridge, (b) a cantilever bridge, (c) a rigid frame bridge, (d) a special problem in steel or concrete building design, (e) the design of any other structure of particular interest to the student provided he has had the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports.

2742. *STRUCTURAL ENGINEERING RESEARCH.* Students wishing to pursue one particular branch of structural engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction, theoretical work with a view of simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2743. *STRUCTURAL ENGINEERING SEMINAR.* Credit 1–6 hrs. Open to specially selected seniors or graduate students. Preparation and presentation of topics of current interest in the field of structures for informal discussion.

2744. *SPECIAL TOPICS IN STRUCTURAL ENGINEERING.* Study in one or more of the specialized topics of civil engineering such as tanks and bins, suspension bridges, towers or movable bridges, which are not covered in the regular courses. Independent design or research projects may also be selected.

## SPECIAL AND GRADUATE COURSES

2801. *THESIS.* The thesis gives the student an opportunity to work out a special problem or to make an engineering investigation, to record the results of his work, and to obtain academic credit for such work. Registration for thesis must be approved by the professor in charge at the beginning of the semester during which the work is to be done.

NOTE: Individual courses may be arranged to suit the requirements of graduate students. These special courses are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom and working either independently or in conjunction with others taking the same course.

## ADMINISTRATIVE ENGINEERING

Messrs. CRANDALL and GEBHARD.

2901. *CONSTRUCTION METHODS.* Credit 3 hrs. 3 Rec. Introduction to methods, equipment, and management principles and procedures involved in construction enterprises; nature of the construction industry and sources of information concerning it; problems and oral reports by students based on current literature; correlation of money, men, materials, machines, and design details to produce economic results.

2902. *ENGINEERING LAW.* Credit 3 hrs. 3 Rec. Basic features of laws of contract, tort, agency, real property, water rights, forms of business organizations, sales, negotiable instruments, workmen's compensation, mechanics' liens, bankruptcy, wills, patents, copyrights, trademarks; work of the expert witness; special emphasis on contract documents used in construction work.

2903. *ECONOMICS OF ENGINEERING.* Credit 3 hrs. 3 Rec. Prereq., 2901, 3231. Principles governing the economic aspects of engineering decisions; time-value of money; economic selection of materials, equipment, and structures; retirement and replacement studies; economic studies for public works. Techniques in estimating costs of engineering construction projects.

2904. *PUBLIC ADMINISTRATION.* Credit 3 hrs. 3 Rec. Administrative aspects of federal, state, and local governments of particular interest to engineer-administrators; government functions which affect the engineer; procedures and practices; general problems of the city; city planning and zoning; revenues and expenditures; budgets; controlling legislations; civil service; and related topics.

2905. *VALUATION ENGINEERING.* Credit 3 hrs. 3 Rec. Prereq., 2901, 2902, 2903, 3231. Theory and practice of estimating the present worth of specific properties

for utility rate making; buying and selling, eminent domain and condemnation proceedings, securities; bank loans, mortgages, insurance, uniform systems of accounting, and improving management.

2906. *ADVANCED ENGINEERING LAW.* Credit 3 hrs. 3 Rec. Prereq., 2902. An extension by the use of case material of some of the legal principles covered in 2902, particularly those which apply to construction contracts, and employer-employee relationships; also additional coverage in suretyships, insurance, bailments, and conditional sales.

2907. *CONSTRUCTION MANAGEMENT.* Credit 3 hrs. Prereq., 2901, 2902, 2903, 3231. Top level planning and operation of construction projects by the civil engineer; coordinated organization and control of men, materials, and machines; scheduling, estimating, purchasing, selection, and training of employees; operation and maintenance of equipment; cost control and pay systems; accident prevention; and other topics. Special reports required.

2941. *PROJECT. ADMINISTRATIVE ENGINEERING.* Credit 3 hrs. Prereq., 2901, 2902, 2903. Development of a public or private engineering project selected by the student involving economic analysis, planning, design, and construction procedures, with special emphasis on the legal, financial, and management aspects.

2942. *ADMINISTRATIVE ENGINEERING RESEARCH.* Credit 3 hrs. Prereq., 2901, 2902, 2903. Investigation of special problems relating to the economic, legal, financial, and management aspects of public and private engineering operations of interest to the engineer-administrator, consulting engineer and constructor.

2943. *ADMINISTRATIVE ENGINEERING SEMINAR.* Credit 1–6 hrs. Prereq., 2901, 2902, 2903. Guided study and discussions by small groups of selected students of topics which involve the legal, financial, and management aspects of civil engineering in public and private work, including discussions of current technical papers and publications.

# MECHANICAL ENGINEERING

The courses in mechanical engineering are listed under the following headings: Drafting and Industrial Design, Thermal Engineering, Industrial and Engineering Administration, Machine Design, Materials Processing.

Required courses in the mechanical engineering curriculum given outside the College of Engineering are as follows (pages 111–118):
Chemistry 105, 106. General Chemistry
Chemistry 301. Introduction to Organic Chemistry
Chemistry 402. Introduction to Physical Chemistry
English 111, 112. Introductory Course
Mathematics 161, 162, 163. Analytic Geometry and Calculus
Physics 115. Mechanics
Physics 116. Wave Motion, Sound, and Heat
Physics 117. Electricity and Magnetism
Physics 118. Physical Electronics and Optics
Public Speaking 101.

Required courses in mechanics of engineering, strength of materials, and engineering materials are described on pp. 77–80.

## GENERAL

3001. *INTRODUCTORY ENGINEERING.* Credit 1 hr. 2 Lect. An orientation to the School and to the field of mechanical engineering. A study of the slide rule, problems in engineering, plotting of data, and report writing.

3002. *INTRODUCTORY ENGINEERING.* Credit 2 hrs. 2 Lect. A continuation of Course 3001 with special emphasis on the responsibilities and opportunities that exist for mechanical engineers in industry. An introduction to modern industrial organization.

3041. *NONRESIDENT LECTURES.* Terms 9 and 10. Required. Total credit 1 hr. for both terms. Fall and spring. 1 Lect.

The course consists of a series of lectures given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life.

3051. *A.S.M.E. STUDENT BRANCH.* Credit 1 hr. Students who have completed at least two terms in the School of Mechanical Engineering are urged to become members of the Cornell Student Branch of the American Society of Mechanical Engineers. The meetings of the Society, however, are open to all. Attendance at any fourteen Student Branch meetings entitles the member to one hour elective credit; however, only one elective hour may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, West Sibley Basement, or to the Honorary Chairman of the Student Branch, Israel Katz, Associate Professor of Mechanical Engineering.

## DRAFTING AND INDUSTRIAL DESIGN

Messrs. BAIRD, BROWNLOW, CLEARY, HEINZMAN, MORDOFF, and SIEGFRIED.

3111. *DESCRIPTIVE GEOMETRY AND FREEHAND DRAWING.* Credit 3 hrs. Fall. 1 Lect. 2 Lab. Introduction to prerequisite arts and sciences of mechanical drafting and creative sketching; lettering; delineation; isometric; descriptive geometric anatomy; freehand pictorial and orthometric drawing; esthetics; introductory creative sketching.

3112. *BASIC MECHANICAL DRAFTING AND CREATIVE SKETCHING.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3111. Basic mechanical drafting principles and standards; creation, expression and interpretation of specifications for the properties of mechanical anatomy by layouts and working drawings; continuation of creative sketching.

3114. *FREEHAND DRAWING.* Credit 1 hr. Fall. 1 Lect. For students who desire only the freehand content of 3111.

3115. *CREATIVE SKETCHING.* Credit 1 hr. Spring. 1 Lect. Prereq., 3111 or 3114. For students who desire only the creative sketching content of 3112.

3116. *INTRODUCTION TO INDUSTRIAL DESIGN.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3111 and 3112. Demonstration of interrelationships of form, function, and materials by special exercises in designing practical structures for appearance. Presentations by a variety of media using perspective, other types of graphic representations, and models.

3117. *DESCRIPTIVE GEOMETRY.* Credit 2 hrs. Fall. 2 Lab. Same as 3111 except that freehand content is omitted.

3118. *BASIC MECHANICAL DRAFTING.* Credit 2 hrs. Spring. 2 Lab. Same as 3112 except that creative sketching content is omitted.

3131. *SPECIAL PROBLEMS IN DRAFTING AND INDUSTRIAL DESIGN.* Credit based upon actual hours of work. Fall or spring. Lab. as required. Open to a limited number of qualified undergraduates and graduate students.

3198, 3199. *INDUSTRIAL DESIGN PROJECT.* Total credit 6 hrs. Ninth and tenth terms. 2 Lab. Prereq., 3116. Projects which integrate training in mechanical engineering when such work is done principally in the field of industrial design.

## INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. ALLEN, BECHHOFER, GAVETT, HALL, HANSELMAN, JOHNSON, KAO, KRICK, LOBERG, McGARRAH, MOORE, PAJKOWSKI, SAMPSON, SAUNDERS, and SCHULTZ.

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING.* Credit 3 hrs. Fall and Spring. 2 Lect. 1 Comp. Basic course in principles of industrial accounting including controlling accounts; special journals and ledgers; voucher system; manufacturing cost systems.

3232. *PERSONNEL MANAGEMENT.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3241 or permission. Techniques of employee selection and evaluation, job evaluation, training, motivation; personnel department organization and interdepartmental relations.

3233. *REPORT WRITING.* Credit 1 hr. Offered on demand. 1 Rec. Engineering students only. Organization of engineering material into concise written form; preparation of engineering reports including organization, description of apparatus and procedures, graphical presentation and summary of results; business letters; written specifications.

3235. *INDUSTRIAL ORGANIZATION AND MANAGEMENT.* Credit 3 hrs. Fall and spring. 3 Lect. Management of an industrial enterprise; internal organization; effect of type of product, methods of manufacture, size of enterprise, and personnel involved; types of enterprises; plant location; centralization and decentralization trends; diversification and specialization; growth of industry.

3236. *ORGANIZATION AND MANAGEMENT OF PRODUCTION.* Credit 3 hrs. Spring. 2 Lect. 1 Rec. Introductory course in industrial management covering organizational structure; principles of mass production; plant location and layout; methods analysis and time study; production planning and control; related functions of engineering, research, sales, purchasing, and cost control; technology, technical organization, and background of scientific management.

3241. *INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Fall and spring. 2 Rec. 1 Comp. Prereq., Calculus. Applications of probability theory and statistics to industrial and engineering problems; point and confidence interval estimation; statistical testing of hypotheses; properties of binomial, Poisson, and hypergeometric distributions, and applications to sampling inspection problems; large-sample theory and the normal distribution, small-sample theory and Student's T and the Chi-square distributions; introduction to correlation theory and curve fitting by least squares.

3242. *STATISTICAL CONTROL AND SAMPLING INSPECTION.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 3241 or permission. Underlying theory, assumptions, applications, and limitations of control charts and sampling plans; concept of statistical control, Shewhart control charts, and sampling inspection for attributes and variables; organization, administration, and economic problems, and application of concepts to areas other than quality maintenance.

3243. *INTERMEDIATE INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 3241 or permission. Application of statistical methods to the efficient design, analysis, and interpretation of industrial and engineering experiments; rational choice of sample size for various statistical tests and the operating characteristic curves of these tests; curve fitting by least squares; introduction to the analysis of variance; statistical multiple decision procedures.

3244. *ADVANCED INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereq., 3243 or permission. Use and analysis of experimental designs such as randomized blocks and Latin squares; analysis of variance

and covariance; factorial experiments; statistical problems associated with finding best operating conditions; selected statistical techniques.

3246. *PRINCIPLES OF INDUSTRIAL ACCOUNTING.* Credit 2 hrs. Fall. 1 Lect. 1 Comp. Basic accounting theory; special journals; controlling accounts and subsidiary records; voucher system; basic manufacturing cost accounting.

3247. *PRINCIPLES OF COST CONTROL.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3246, 3231, or equivalent. Principles of cost accounting for production order and continuous process operations; cost factors related to decision making, control and profit; budgets and standards.

3253. *CHEMICAL ENGINEERING COST ACCOUNTING.* Credit 3 hrs. Fall and spring. 2 Lect. 1 Comp. Basic accounting theory; manufacturing cost accounting and cost analysis in the chemical industry; standards, budgetary control, profit analysis and statement analysis discussed briefly.

3254. *STANDARD COSTS AND MANAGEMENT CONTROL.* Credit 3 hrs. Fall. 1 Lect. 2 Comp. Prereq., 3247, 3250, or 3253. Profit analysis, static and flexible budgets, standard costs, and cost analysis applied to production and sales; new conceptions of control, decision problems, cost aspects of engineering and management decision.

3261. *SURVEY OF INDUSTRIAL ENGINEERING.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3247 or 3250, 3404 or equivalent. Methods engineering; motion and time study; process planning; plant layout; materials handling; engineering economics; production management.

3262. *METHODS ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 2 Lab. Prereq., 3241 or equivalent. Design of operations and jobs; analytical techniques and factors influencing creation and selection of optimum designs from alternatives; work measurement techniques including stop-watch time study and predetermined motion times as used for evaluation of design, control of operations, wage standards, etc.

3263. *PRODUCTION ENGINEERING.* Credit 3 hrs. Fall. 1 Lect. 2 Comp. Prereq., 3247 or 3250, 3262, 3404, or permission. Principles of engineering economy as analytical tool in examination of alternatives; analysis of product design from standpoint of manufacturing; determination of methods of processing and assembly, i.e., machine, tool, jig, and fixture requirements.

3264. *PRODUCTION ENGINEERING.* Credit 3 hrs. Spring. 1 Lect. 2 Comp. Prereq., 3263. The analysis and design of integrated manufacturing systems; principles of materials handling, plant layout, production scheduling, and inventory control. Emphasis on the interdependency of engineering and control functions.

3265. *PRODUCTION CONTROL.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 3241, 3264. Programing manufacturing operations; production forecasting, scheduling, dispatching, follow-up; inventory control; linear programing and statistical methods as techniques to establish decision rules for these functions.

3266. *ADVANCED METHODS ENGINEERING.* Credit 3 hrs. Fall, 2 Rec. 1 Lab. Prereq., 3262 or permission. Critical appraisal of methods engineering; maintenance of time standards; work sampling techniques; macroscopic and microscopic standard data; methods-time measurement; psychological and sociological factors in methods design; design and measurement of nonrepetitive task; restriction of output; resistance to change.

3267. *ADVANCED PRODUCTION ENGINEERING.* Credit 2 hrs. Spring. 2 Rec. Prereq., 3264 or permission. Discussion of possible solutions of typical production problems and situations; technical and economic aspects; in-process and between-process handling problems; current trends and concepts of automation.

3270. *INDUSTRIAL MARKETING.* Credit 3 hrs. Spring. 3 Lect. Prereq., 3241, 3247, or 3250. Industrial marketing as related to product planning, policy, and research; sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Aspects of related purchasing problems; methods of forecasting sales.

3271. *INDUSTRIAL MARKETING RESEARCH.* Credit 3 hrs. Fall. Prereq., 3270. Techniques of market research applied to specific problems related to industrial goods.

3280. *INTRODUCTION TO OPERATIONS RESEARCH.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 3241, 3254, or permission. Methodology and techniques of operations research including linear programing, queuing, data processing and computing techniques, simulation; applications to production, cost, inventory, and sales problems.

3290. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.* Credit and sessions as arranged. Fall and spring. Offered to qualified students individually or in small groups. Study, under direction, of special problems in the field of industrial and engineering administration.

3298, 3299. *PROJECT.* Max. credit 6 hrs. Prereq., thru 3264, or special permission. Individual or group investigations of selected industrial problems to emphasize the technical, functional, organizational, and personnel relationships involved in modern industry. The credit hours allotted will be dependent on the quality and quantity of work done.

## MACHINE DESIGN

Messrs. BURR, DuBOIS, GAGNE, MABIE, OCVIRK, PHELAN, RAVEN, and WEHE.

3341. *MACHINE DESIGN.* Credit 4 hrs. Spring. 3 Rec. 1 Lab. Prereq., 1153, 1223, 3118, 3402, and 6110, or equivalent. Required of students in electrical engineering and may be elected by other qualified students not in mechanical engineering. The design of machines and machine members based upon considerations of motion, size, material, strength, durability, and manufacturing processes; selection of cams, linkages, couplings, clutches, brakes, bolts, chains, gears, bearings, shafts, springs, and fasteners.

3351. *MECHANISM.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3112, 1151. A study of displacements, linkages, cams, gears, belts, and trains of mechanism.

3352. *DYNAMICS OF MACHINERY.* Credit 3 hrs. Spring. 3 Rec. Prereq., 3351 and 1152. Graphical and analytical studies of velocities and accelerations and of static and inertia forces in mechanism; engine force analysis, flywheels, and balancing; gyroscopic loads; shaft whirl; vibration isolation.

3353. *DESIGN OF MACHINE MEMBERS.* Credit 3 hrs. Fall. 1 Lect. 2 Lab. Prereq., 3351, 1153, 1221. Application of mechanics, kinematics, materials and processes to the design and selection of springs, couplings, clutches, brakes, belts, chains, gears, shafts, bearings, fastenings, and pressure vessels; stress concentration, residual stresses, theory of lubrication.

3354. *DESIGN OF MACHINES.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3353, 3404, 6112 (prereq. or parallel). The design of complete machines and modification of existing machines; computations and layout drawings as required; the design of castings, forgings, stampings, weldments, housings, and hydraulic systems for machines.

3361. *ADVANCED MACHINE ANALYSIS.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3353, 1155 (prereq. or parallel). Advanced analyses of mechanisms and machinery members such as clutches and brakes; the graphical determination of shaft deflection; prob-

lems in impact, creep, thermal stress, residual stress, surface stress, pressure vessels, and rotating disks; an extended treatment of bearing lubrication.

3366. *ADVANCED KINEMATICS.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 3352. Advanced graphical and semigraphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and unique linkages. Synthesis of mechanism.

3367. *DESIGN PROBLEMS IN VIBRATIONS AND DYNAMICS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 1155, 3352. Applications of dynamics and vibration theory to the design of machinery; vibration and shock mounting of machines with single and multi-degrees of freedom, properties of isolators, damping devices, critical speeds of shafts and crankshaft systems; vibration instruments and experimental investigations.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Credit arranged. Either term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis or experimental investigation of a machine or component of a machine, or studies in a special field of machine design.

3372. *EXPERIMENTAL METHODS IN MACHINE DESIGN.* Credit 3 hrs. Fall. 1 Rec. 2 Lab. Prereq., 3353. Investigation and evaluation of methods used to obtain design and performance data. Techniques of photoelasticity, strain measurement, photography, vibration and sound measurements, balancing methods, and development techniques are studied as applied to machine design problems.

3373. *CREATIVE DESIGN.* Credit 2 hrs. Fall. 2 Lab. Prereq., 3354. Use of short ingenuity problems to stimulate originality; layout design emphasizing methods of development of improved designs.

3375. *MACHINERY SURVEY.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 3351. A study of automatic and semiautomatic machinery such as dairy, canning, wire-forming, textile, machine-tool, computing, and printing equipment. Recommended as a Term 6 or 8 elective for students considering a design project.

3376. *DESIGN OF OIL HYDRAULIC MACHINERY.* Credit 3 hrs. Spring. 3 Rec. Prereq., 3353, and either 2331 or 3604. Methods of generation, application, and control of oil hydraulic power, commercial forms of fixed and variable delivery pumps, fluid motors, valves, control circuits, multispeed and sequence systems, pilot, servo, and tracer mechanisms for use in machine tools and similar applications.

3377. *AUTOMOTIVE ENGINEERING.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3353. Analysis of various designs for the parts of an automotive vehicle, other than the engine, relative to its performance; stability, weight distribution, traction, steering, driving, braking, riding comfort, power required and available, transmission types, acceleration, and climbing ability. Recommended together with Course 3670 for a study of automotive engineering.

3398, 3399. *PROJECT.* Total credit 6 hrs. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of machine design. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

## MATERIALS PROCESSING

Messrs. CARPENTER, CRISSEY, DISPENZA, GEER, HUSON, and MORGAN.

3402. *MACHINE TOOLS.* Credit 2 hrs. Both terms. 1 Lect. 1 Lab. Lectures, demonstrations, and laboratory practice on basic machine tools and their accessories; project layout and operation sequence exercises for unit making of goods; demonstrations of production tooling and gaging.

3403. *FUNDAMENTALS OF MACHINE TOOLS.* Credit 1 hr. Both terms. 1 Lab.

Demonstrations and practice on basic machine tools and their accessories; use of unit measuring instruments.

3404. *PRODUCTION MACHINE TOOLS.* Credit 2 hours. Both terms. 1 Lect. 1 Lab. Prereq., 3406, 3262. Lectures, demonstration studies, and analyses of machine tools for quantity production of goods; jigs, fixtures, and other tooling accessories are investigated; operation analysis and quality limitations are discussed and demonstrated

3405. *GAGE LABORATORY.* Credit 1 hr. Both terms. 1 Lab. Demonstration studies of measuring devices and techniques for control of size, form, and alignment of commercial goods to A.S.A. and other standards; laboratory practice in inspection methods; quality control data studies; calibration and gage checking.

3406. *MACHINE TOOL TECHNOLOGY.* Credit 2 hrs. Both terms. 1 Lect. 1 Lab. Study of chip formation, cutting tools and fluids, speeds and feeds, and their relations to machinability; analyses of general purpose machines and their accessories; machining practice including layouts, set-ups, and use of measuring instruments.

3407. *ADVANCED MATERIALS PROCESSING.* Credit and hours as arranged with department. Special work in selected areas of mechanical technology; topics and extent of study assigned to suit individual or group needs.

3411. *CUTTING TOOLS.* Credit 3 hrs. Both terms. 2 Lect. 1 Lab. Prereq., 3404, 1152, 1231. Physics of chip formation; tool life, Woxen's and Ernst-Merchant equations; machinability factors; tool preparation; cutting fluid performance; work-tool relations.

3412. *MACHINE TOOL OPERATIONS.* Credit 3 hrs. Both terms. 2 Lect. 1 Lab. Prereq., 3404, 3262, 3405. An advanced and detailed study of production machinery and tooling; operation sequence; fixture and cutter selection; transfer schemes; special machinery; quality limitations.

3413. *MACHINE TOOL ANALYSIS.* Credit 3 hrs. Both terms. 1 Lect. 2 Labs. Prereq., 3404, 3262, 3351. An intensive investigation of machine tool capacities, standard tooling and dimensions of elements; analysis of power drives, speeds and feeds; performance studies; vibration and rigidity problems; maintenance and lubrication; machine tool manufacture; industrial needs and development trends.

3425. *ADVANCED GAGE LABORATORY.* Credit 3 hrs. Both terms. 1 Lect. 2 Labs. Prereq., 3405, 1222, 3241. Intensive study of gaging principles and practices; quality control applications; continuous gaging and automatic sorting; selective assembly; noncontact and nondimensional inspection; machine tool inspection standards.

3498, 3499. *PROJECT.* Total credit 6 hrs. Hours of credit for each course will depend upon the amount and quality of work done each term. Work of the 9th and 10th terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of materials processing.

## THERMAL ENGINEERING

Messrs. ANDRAE, CLARK, CONTA, DROPKIN, ERDMAN, FAIRCHILD, GAY, GEBHART, KATZ, KENYON, MACKEY, SHEPHERD, and WATSON.

3601. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Fall. 2 Lect. 1 Comp. Prereq., Mathematics 163, Physics 116, Chemistry 106. Laws of thermodynamics; energy equations; properties of state of ideal and real fluids; processes; basic cycles of heat engines and heat pumps; properties of mixtures.

3602. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3601, Chemistry 402. Properties of a pure substance; Maxwell relations, thermodynamics of combustion; availability, irreversibility, and equilibrium: thermodynamic analysis of complex cycles.

3603. *FLUID PROPERTIES AND MASS FLOW.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3601, 1152. Properties of the continuum; dimensional analysis; flow of incompressible and compressible fluids; laminar flow, turbulent flow, boundary layer; reversible and irreversible flow; shock; effects of friction, heat transfer, and area change.

3604. *FLOW PROCESSES AND ENERGY TRANSFER.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3603. Momentum relations; energy relations; rotational and irrotational flow; energy exchange between fluid and a rotor; compressors; gas and vapor turbines; metering and control of flow. Laboratory instruction in pressure measurement, friction effects, flow characteristics, flow metering, characteristics of fluid machinery.

3605. *HEAT TRANSFER.* Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Lab. Prereq., 3603, 1155. Introduction to heat transfer by conduction, convection, and radiation; steady state, transient state; steady periodic state; heat transfer in engineering apparatus; numerical methods; electrical and fluid analogues. Laboratory instruction in temperature measurement, determination of surface coefficients, radiant energy exchange, and experimental use of analogues.

3606. *THERMAL ENGINEERING LABORATORY.* Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereq., 3602, 3604, 3605. Methods of testing; experimental determination of performance characteristics of engines, turbines, steam generating units, pumps, compressors, fans, refrigerating systems, air conditioning apparatus, auxiliaries and components of complete plants; analysis of experimental data; preparation of engineering reports.

3607. *COMBUSTION ENGINES.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to combustion engines with emphasis on application of thermodynamics, fluid dynamics, and heat transfer; reciprocating combustion engines; gas turbines; compound engines; reaction engines.

3608. *THERMAL POWER PLANTS.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to steam and binary vapor power plants with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; nuclear power.

3609. *REFRIGERATION AND AIR CONDITIONING.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to refrigeration and air conditioning with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; compression, absorption, and other systems of refrigeration; control of the physical environment.

3620. *ENGINEERING IN FOOD PROCESSING.* Credit 3 hrs. Fall. 3 Lect. Prereq., elementary physics and chemistry. Primarily for students in the College of Agriculture and School of Nutrition; not open to engineering students. Introduction to engineering principles of construction and operation of mechanical and electrical equipment used in the preservation and storage of foods.

3630. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Spring. 3 Rec. Required of students in the School of Electrical Engineering. Prereq., Mathematics 163, Physics 116, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of gases, vapors, and mixtures; nonflow and flow processes; gas and vapor cycles.

3641. *HEAT-POWER I.* Credit 3 hrs. Fall. 2 Lect. 1 Comp. Required of students in the School of Civil Engineering. Prereq., Mathematics 163, Physics 116, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of gases; gas processes and gas cycles; internal combustion engines; the compressed air plant.

3642. *HEAT-POWER II.* Credit 2 hrs. Spring. 2 Lect. Required of students in the School of Civil Engineering. Prereq., 3641. Properties and processes of vapors; steam engines; steam turbines; the elementary steam power plant; fundamentals of heat transfer with applications to problems in heat transfer of special interest to students in civil engineering.

3650. *THERMAL ENGINEERING RESEARCH.* Credit to depend upon hours of actual work; informal instruction will be given to a limited number of undergraduates and graduate students interested in work to supplement that given in required courses in combustion engines, power generation, heat transfer, refrigeration, air conditioning, and instruments; permission of the department necessary for registration.

3651. *GRAPHICAL SOLUTIONS.* Credit 3 hrs. 3 Rec. Elective for undergraduate students who have completed four terms or for graduate students. Design of slide rules, network charts, and alignment charts; use of dimensional analysis in the planning and correlation of experiments; derivation of empirical equations to fit experimental data.

3661. *ADVANCED THERMODYNAMICS.* Credit 3 hrs. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3601, 3602, or equivalent. A rigorous and general treatment of the laws of thermodynamics with emphasis on mathematical development and philosophical interpretations; the pure substance; homogeneous and heterogeneous systems; Gibbs and Helmholtz functions; Maxwell relations; availability and irreversibility; equilibrium.

3662. *GAS TURBINE PLANTS.* Credit 3 hrs. 3 Lect. Prereq., 3601, 3602, or equivalent. Fundamental study of the cycles and apparatus of the modern gas turbine plant; performance and suitability of this type of power plant for various applications.

3663. *PRINCIPLES OF TURBOMACHINERY.* Credit 3 hrs. 3 Lect. Intended for graduate students but open to qualified fifth year students. Prereq., 3602, 3603, 3604, or equivalent. Transfer of energy between a fluid and a rotor; application of thermodynamics and fluid dynamics to rotating machinery; centrifugal and axial flow pumps, compressors, and turbines.

3665. *ADVANCED HEAT TRANSFER.* Credit 3 hrs. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3605 or equivalent. Analytical and numerical methods of solving problems on heat transfer in the steady, transient, and periodic states; electrical and fluid analogs; heat flow with heat sources and sinks; analogies between transfer of momentum and transfer of heat; heat transfer with liquid metals.

3666. *ADVANCED AIR CONDITIONING.* Credit 3 hrs. 3 Rec. Prereq., 3609, or equivalent. Selected studies of air conditioning principles and apparatus; panel heating and cooling; heat pumps; solar loads and solar collectors; air conditioning in transportation.

3667. *TEMPERATURE MEASURING INSTRUMENTS.* Credit 2 hrs. 1 Lect. 1 Lab. Intended for graduate students but open to qualified fifth year students. Prereq., 3605, or equivalent. Theory, construction, calibration, and application of liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, electrical resistance thermometers, thermoelectric thermometers, optical pyrometers, radiation pyrometers and other temperature measuring devices.

3668. *AUTOMATIC CONTROL ENGINEERING.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 3604, 3606. Modes of automatic control; elements of industrial controllers; process characteristics; automatic control systems.

3669. *DIESEL ENGINEERING.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 3606, 3607. Design and construction of diesel engines, fuel injection systems, and combustion

chambers; fuels and lubricants; engine governing; supercharging; experimental study of performance characteristics.

3670. *ADVANCED COMBUSTION ENGINES.* Credit 3 hrs. 1 Rec. 2 Comp. Prereq., 3607. Design and operation of combustion engines for automotive, marine, and industrial uses; special emphasis upon spark-ignition engines; matching of engine supply power and propulsion demand power.*

3671. *AIRCRAFT POWER PLANTS.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3602. Thermal, mechanical, and operating characteristics of reciprocating and rotating aircraft power plants; studies augmented by reading of technical papers and solutions of problems.

3672. *AIRCRAFT ENGINE DESIGN.* Credit 3 hrs. Spring. 3 Rec. Prereq., 3602, 3354. Engine design principles and pertinent thermodynamic calculations; design of engine components with regard to functions and loads.

3698, 3699. *PROJECT.* Total credit 6 hrs. Work of the ninth and tenth terms to integrate the training in mechanical engineering, principally in the fields of thermodynamics, fluid dynamics, heat transfer, combustion engines, power plants, refrigeration, and air conditioning.

# ELECTRICAL ENGINEERING

*COURSES BY GROUPS...* Within the School of Electrical Engineering, courses are numbered in groups, with each course designated by a four-digit number in which the first digit is 4. The second digit denotes the course groups, and the third and fourth digits identify the course within the group.

The descriptions of courses offered in the School of Electrical Engineering follow. Courses in other divisions required of students in electrical engineering are described on pages 111–118.

## GENERAL COURSES

4011. *DIMENSIONAL ANALYSIS.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. The concept of physical dimensions, fundamental and derived quantities, systems of fundamental quantities and units, solution of simple problems by dimensional analysis, determinants and matrices, homogeneous equations, homogeneous functions, linear dependence, Buckingham's $\pi$- Theorem and its application to physical problems and to model experiments.

4021. *ENGINEERING REPORTS.* Credit 3 hrs. Fall. 3 Lect.-Rec. The development of the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to write and present technical reports that meet professional standards.

4022. *ELECTRICAL ENGINEERING ECONOMY.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. The principles underlying the selection of the most economical method of accomplishing an engineering objective, including interest, depreciation, return on investment, planning of plant expansion, and the theory and practice of setting rates.

4041 and 4042. *NONRESIDENT LECTURES.* Credit 1 hr. for both terms. Fall and spring. 1 Lect. Lectures given by lecturers invited from industry and from certain other departments of the University to assist students in their approach to employment and in their transition from college to industrial life.

4091 and 4092. *PROJECT.* Credit 3 hrs. Fall and spring. Individual study, analysis, and usually experimental tests in connection with a special engineering problem chosen by the student after consultation with the faculty member directing his project; an engineering report on the project is required.

*Recommended together with Course 3377 for a study of automotive engineering.

## COURSES IN BASIC ELECTRICAL ENGINEERING

4110. *PRINCIPLES OF ANALYSIS IN ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall. 3 Rec. 1 Comp. Prereq., Math. 162, Phys. 116. Power and energy; measurement of electrical quantities; direct current networks and network theorems; magnetic fields and magnetic circuits; electrostatic fields and relationships in dielectrics; electromagnetic relationships; stored magnetic and electric energy; elementary transients in circuits containing resistance and either inductance or capacitance.

4111. *ELEMENTARY ALTERNATING CURRENT CIRCUITS.* Credit 3 hrs. Spring. 3 Rec. 1 Comp. Prereq., Math. 163, Phys. 117, 4110. Elementary a-c circuit elements; power, power factor, energy relationships; real and reactive power, application of vector algebra; series and parallel circuit elements; resonance; loci; a.c. networks and network theorems; mutual inductance, coupling coefficient, leakage inductance; air and iron core transformers and vector diagrams.

4112. *ALTERNATING CURRENT NETWORKS.* Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Comp. Prereq., Math. 607, 4111. Polyphase circuits and power measurement; phase sequence effects; balanced and unbalanced conditions; nonsine waves in polyphase systems; four terminal network; A, B, C, D, constants, open and short circuit impedances; image impedances, and transfer constants; the concept of a complex frequency; problems involving the complex frequency plane.

4113. *TRANSMISSION LINES AND FILTER NETWORKS.* Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Comp. Prereq., 4112. Steady state solution, characteristic impedance and propagation constant; reflection coefficient; vector diagrams; impedance charts as graphical aids; transmission line networks; impedance transformations; network image and iterative operation, transfer constants; constant K, m derived, and lattice types; Foster's theorem; Bartlett's theorem; composite filter design; wave guides; transmission line analogue in solution of guide problems; modes; impedance transformations.

4114. *TRANSIENTS IN LINEAR SYSTEMS.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereq., 4112. Transient behavior of circuits with lumped constants; the classical solution of single- and double-energy circuits in the transient state; the ordinary linear differential equation; the Laplace transformation; systems of ordinary linear differential equations, their Laplace transformation, and their solution.

4115. *TRANSIENTS IN CIRCUITS WITH DISTRIBUTED CONSTANTS.* Credit 4 hrs. Spring. 2 Lect. 1 Comp. Prereq., 4113, 4114. Functions of real and complex variables, infinite series, and Laplace and Fourier transforms; the application of these subjects to problems involving transients in transmission lines and networks.

4116 *ELECTRIC CIRCUIT LABORATORY.* Credit 3 hrs. Fall. 1 Lect. 1 Lab. Must be preceded or accompanied by 4112. D-c circuits and parameters; d-c bridges; temperature measurements; heat flow; instruments; calibration and standards; transients.

4121. *ELECTRON TUBES AND CIRCUITS.* Credit 4 hrs. Spring. 2 Lect.-Rec. 1 Comp. 1 Lab. Prereq., 4121. Emission; conduction in high vacuum and gas; cathode-ray tubes; high-vacuum, crystal, and thermionic gas diodes; cold-electrode gas-discharge tubes; rectification and filtering; thyratrons, pool-type tubes, polyphase rectifiers, and electronic light sources; high-vacuum triode characteristics, parameters, and equivalent circuits.

4122. *ELECTRONIC CIRCUIT ELEMENTS.* Credit 4 hrs. Fall. 3 Lect-Rec. 1 Lab. Prereq., 4121. Multigrid vacuum-tube characteristics, parameters, and equivalent circuits; transistor characteristics, parameters, and equivalent circuits; application of linear equivalent circuits in devices using high-vacuum tubes and transistors; studies of air-core and iron-core transformers as used in communication systems;

studies of small-signal and large-signal amplifiers using high-vacuum tubes and transistors.

4123. *ELECTRONIC CIRCUIT ELEMENTS.* Credit 4 hrs. Spring. 3 Lect-Rec. 1 Lab. Prereq., 4122. Studies of feedback systems using positive and negative feedback; amplitude and angular modulation and demodulation; multivibrators and blocking oscillators; simple wave-shaping circuits; elements of electronic computers.

4216. *ELECTRICAL MACHINERY LABORATORY.* Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4116. D-C magnetization; d-c motors; d-c controllers; d-c generators; amplidyne; loss separation; a-c magnetization; a-c bridges.

4221. *ALTERNATING CURRENT MACHINERY.* Credit 4 hrs. Fall. 1 Conf. 1 Comp. Prereq., 4112. Theory, construction and operating characteristics of transformers, induction motors, synchronous machines, and single-phase motors.

4226. *ELECTRICAL MACHINERY LABORATORY.* Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4221. Magnetization and circuits with nonsinusoidal voltages. Harmonics in polyphase systems; instrument, constant current and constant potential transformers; single-phase and polyphase induction motors; synchronous machines.

## COURSES IN POWER SYSTEMS AND MACHINERY

4321. *ELECTRICAL MACHINE THEORY.* Credit 3 hrs. Fall. 1 Conf. 1 Comp. Prereq., 4226. Space harmonics; parasitic torques; two-reaction analysis; transient impedances; symmetrical component impedances; single-phase motor analysis; commutator-type a-c machines.

4326. *ELECTRICAL MACHINERY LABORATORY.* Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereq., 4321. Salient-pole synchronous machines; induction motor loss separation; energy metering; special topics.

4351. *POWER SYSTEMS I.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4113, 4226, or equivalent. Steady-state performance of electric power systems; steady-state electrical characteristics and equivalent circuit elements of static loads, rotating machines, transformers, and transmission circuits; steady-state circuit analysis of the power system network with the aid of the network analyzer; control and regulation of the power system to maintain normal operating conditions; use of digital and analogue computing devices.

4352. *POWER SYSTEMS II.* Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4114, 4226 and 4351, or equivalent. Transient analysis of electric power systems, especially the transients of electromagnetic quantities; characteristics of rotating machines; systems of components used in power system analysis; justification of quasi-steady-state analysis; use of a.c. network analyzers, and electronic differential analyzers in computation.

4353. *POWER SYSTEMS III.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4351, and 4352, or equivalent. Electromechanical transients of power systems; protective schemes against abnormal operation of power systems; large-amplitude, and the small-amplitude swing or oscillation of the synchronous machine rotors; analytical methods in the understanding of the physical phonomena; analysis of protection and control schemes of the power system during abnormal operation.

4371. *HIGH-VOLTAGE PHENOMENA.* Credit 3 hrs. Spring. Prereq., 4351. The problems encountered in the normal operation of power systems at very high voltages, of the abnormal conditions imposed by lightning, of the methods employed to assure proper operation of power systems and apparatus under high-voltage conditions, and of the devices available for laboratory testing of equipment under actual or simulated conditions.

## COURSES IN INDUSTRIAL ELECTRONICS

4411. *ELECTRONIC CONTROL EQUIPMENT.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. prereq., 4123. Principles of electronic instrumentation and electronic control systems; methods of utilizing a stimulus in the form of heat, light, sound, or mechanical motion; industrial circuits including timing circuits, photoelectric controls, motor controls, welder controls, voltage regulators and frequency-varying and frequency-discriminating circuits. Development of original thinking and methods of investigation.

4415. *ADVANCED ELECTRONIC CONTROLS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab.-Comp. Prereq., 4411. An advanced study of the theory, design and characteristics of selected electronic units.

4421. *ELECTRONIC POWER CONVERTERS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab.-Comp. Prereq., 4411. Study of oscillators, mercury-pool rectifiers, and inverters in power sizes covering practical circuits, complete laboratory tests, and comprehensive mathematical treatments.

## COURSES IN RADIO AND COMMUNICATION

4501. *RADIO AND COMMUNICATION SEMINAR.* Credit 1 to 3 hrs. Fall and spring. Primarily for graduate students. Reading and discussion of technical papers and publications in the field of radio and communication.

4511. *RADIO AND COMMUNICATION THEORY.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4113, 4114, and 4123. Study of the transient and steady-state response of circuits; consideration of noise in communication systems; elements of information theory; illustrative examples from fields of television, radar, and computers.

4512. *RADIO AND COMMUNICATION THEORY.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 4565. A study of communication circuits with distributed constants and the production and propagation of electromagnetic radiation; transmission line theory and applications; impedance matching; ultra-high-frequency generation and transmission; electromagnetic theory; propagation phenomena; antenna characteristics and radiation.

4516, 4517. *RADIO AND COMMUNICATION LABORATORY.* Credit 3 hrs. each. Fall and spring respectively. Either or both may be taken. 1 Rec. 1 Lab. Prereq., 4113 and 4123. Choice of three to five different experiments from the fields of electronic circuits, networks, transmission lines, wave guides, and antennas; experiments selected to meet individual needs.

4518. *COMMUNICATION EQUIPMENT SHOP.* Credit 1 hr. Fall. 1 Lect.-Lab. Prereq., 4123. Construction and test of an electronic device; study of circuit components in terms of their application in electronic circuits; the use of hand tools; circuit layout in accordance with good construction practice.

4526. *DESIGN AND CONSTRUCTION OF VACUUM TUBES I.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab. Prereq., 4122. Materials and processing necessary to fabricate simple tubes; considerations involved in heater and cathode design; theoretical aspects of design of diode, triode, tetrode, beam and converter tubes; design, construction, and test of several tubes.

4527. *DESIGN AND CONSTRUCTION OF VACUUM TUBES II.* Credit 3 hrs. Spring. 2 Lect-Rec. 1 Lab. Prereq., 4526. Electron beam formation; cathode ray gun design; traveling wave tube construction; ultra-high-frequency tubes utilizing disc seals and other methods of construction; gas-filled tubes and photo-emissive devices; the use of the electrolytic tank for gun design.

4529. *TRANSISTORS.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., Phys 214 and 4123. Motion of electrons and holes in semiconductors; the physical basis of transistor action and semiconductor rectifiers; application of transistors and semiconductor rectifiers as active or passive elements in circuits for use as amplifiers, oscillators, modulators, switches, photoelectric devices, and other circuits.

4531. *TELEVISION SYSTEMS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4511. Basic work in transient analysis, vacuum tube amplifiers, cathode-ray pickup and viewing tubes, cathode-ray beam deflection, pulse shaping, modulation, and antenna characteristics; further study of television problems; optics, illumination, scanning, synchronization, blanking, and shading are considered.

4541. *APPLIED ACOUSTICS.* Credit 2 hrs. Fall. 2 Lect.-Rec. Prereq., 4123. The laws of ideal gases, the thermodynamic properties of air, and the laws of the propagation of compressional waves; the transmission of sound through tubes, horns, and unbounded media; the design of sound sources, microphones, loudspeakers, and wax, lacquer, magnetic, and photographic recorders; reflection, absorption, and reverberation.

4551. *RADIO AIDS TO NAVIGATION.* Credit 2 hrs. Spring. 2 Lect.-Rec. Prereq., 4123. Long-wave and medium-wave direction finders and radio beacons; atmospheric effects and limitations on accuracy; medium-frequency pulsed transit-time systems and high-frequency return-signal systems, with application to long-range navigation and precision mapping; airport approach systems and traffic control.

4561. *MICROWAVE COMPONENTS AND TECHNIQUES.* Credit 2 hrs. Spring. 2 Lect. Prereq., 4565 and 4512. Should be accompanied by 4517. Electrical equipment particularly applicable to microwave operation; magnetrons, klystrons, and other similar generators; measuring devices; transmission systems; wave guides, coaxial lines, and cavity resonators.

4563. *PULSE TECHNIQUE IN COMMUNICATION AND RADAR.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4114 and 4123. Analysis of signal functions; noise analysis; basic principles of pulse generation, modulation, transmission, and reception; fundamental circuits of pulse techniques; application to radar; pulse communication systems, known as pulse-amplitude, pulse-time, pulse-position, and pulse-code modulating systems.

4564. *TRANSMISSION OF INFORMATION.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4563. The statistical properties of the source; the transformation of primary signal functions into secondary signal functions at the transmitter; the capacity of the channel to transmit the secondary signal function in the presence of channel noise; the possibilities of recovering the primary signal function at the receiver; pulse-code modulation.

4565. *ELECTROMAGNETIC THEORY.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4113. The foundations of electromagnetic theory required for study of radio wave propagation; a critical examination of the significance of the electromagnetic vectors and their relations to a discussion of the principles involved in guided and unguided propagation.

4566. *RADIO WAVES I.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. Influence of the earth, the lower atmosphere, and the ionosphere on propagation of radio waves; the Sommerfeld theory; propagation in an ionized atmosphere; reflection from the ionosphere at both normal and oblique incidence.

4567. *RADIO WAVES II.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4566. The influence of the earth's magnetic field upon ionospheric propagation; diffraction round a spherical earth; propagation in standard and nonstandard atmospheres; scattering.

4568. *ANTENNAS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. The theory of radiation and reception by dipoles, slots, broadside antennas, end-fire antennas, horns, and paraboloids; the detailed electromagnetic field of simple antennas.

4571. *ADVANCED COMMUNICATION NETWORKS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4113. Mesh and nodal analysis; the complex frequency plane; conditions for physical realizability; representation of driving-point and transfer impedance functions by physical networks; topics in the design of impedance functions.

## COURSES IN ILLUMINATION

4611. *INTRODUCTORY ILLUMINATION.* Credit 3 hrs. Fall. 2 Rec. 1 Lab.-Comp. Prereq., Phys. 118. Problems commonly encountered in illumination engineering and the methods of solution; sources of light; visual perception; light control, both spectral and directional; measurement of light sources and illumination; general illumination design; production and mixing of colors; architectural objectives.

4612. *ILLUMINATING ENGINEERING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab.-Comp. Prereq., 4611. Computation of light-flux distribution and study of difficult lighting problems; emphasis on specialized rather than general lighting problems.

4615. *ILLUMINATION SEMINAR.* Credit 2 hrs. Fall. 1 two-hour period each week. Must be accompanied or preceded by 4611. Reports on selected topics of current interest in illuminating engineering.

## COURSES IN SERVOMECHANISMS

4711. *SERVOMECHANISM I.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4123, 4216, 4221, 4226. Principles of servomechanisms, emphasizing analysis of performance from equations and transfer-function plots; Laplace transformations, error detecting devices; hydraulic devices; factors affecting errors, damping, and speed of response; criteria for stability.

4712. *SERVOMECHANISM II.* Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4711. Synthesis of feedback control systems; prediction of performance from stability criteria and comparison with laboratory performance.

4713. *SERVOMECHANISMS SEMINAR.* Credit 2 hrs. Fall. 1 two-hour period. Prereq., 4712. Reports on selected topics in servomechanisms; nonlinear effects on analysis and performance; sampled data systems; power requirements, analogue computers for servo analysis and synthesis; statistical analysis of servomechanisms.

## COURSES IN COMPUTERS

4810. *INTRODUCTION TO ELECTRONIC COMPUTERS.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab. Prereq., 4114 and 4123. An introduction to the field of electronic computing devices, their philosophy, operation, design, principles, and use; detailed treatment of analogue computers; brief discussion of digital and other computers.

4815. *SEMINAR ON FLUID-NETWORK ANALYSIS.* Credit 2 hrs. Spring. 1 two-hour seminar or 1 lab. Prereq., basic courses in fluid mechanics or hydraulics and in electric-circuit theory. The study of fluid flows and pressure losses in pipes or ducts; methods of simplifying networks for analysis and of estimating load requirements; analysis of networks by computational, electrical analogy, and digital-computer methods

4820. *SWITCHING THEORY FOR DIGITAL COMPUTERS.* Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab. Prereq., 4113, 4121. An introduction to the theory and design of switching circuits; discussion of elements used in switching apparatus; detailed consideration of switching algebra and its application to switching circuits.

## ELECTRICAL COURSES REQUIRED IN OTHER ENGINEERING CURRICULA

4931. *ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Comp. Prereq., Math. 163, Mech. 1132 or 1152. An elementary study of direct-current electric circuits; the concepts of resistance, inductance, and capacitance; magnetic circuits; single-phase and three-phase alternating-current circuits; instruments and techniques appropriate for making measurements in all such circuits.

4932. *ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4931. D-C generators and motors; motor starters and controllers; transformers; induction motors; synchronous machines; a-c single-phase motors; d-c and a-c selsyn units.

4933. *ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4932. The characteristics and applications of the various commonly used electron tubes; rectifiers; amplifiers; oscillators: electronic control and instrumentation.

4934. *PRINCIPLES OF AUTOMATIC CONTROL.* Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4933. The mathematics of automatic control as exemplified in servo devices, with analysis of electrical, mechanical, and hydraulic applications; problems of electrical instrumentation in automatically controlled operations and processes.

4983. *BASIC ELECTRICAL ENGINEERING.* Credit 4 hrs. Spring. 1 Lect. 2 Rec. 1 Comp. Prereq., Math. 163, Phys. 117. (Capacitors; simple electrical transients.) Direct-current and alternating-current circuits, magnetic circuits including permanent magnetic material.

4991. *ELECTRONIC CIRCUITS.* Credit 3 hrs. Fall. 3 Lect. For graduate students majoring in an engineering field other than electrical. Alternating-current circuits; characteristics of high-vacuum tubes and transistors; small-signal and large-signal amplifiers; feedback and oscillators; modulation and demodulation; simple wave-shaping circuits.

## CHEMICAL ENGINEERING

5101, 5102. *INTRODUCTORY CHEMICAL ENGINEERING.* Credit 2 hours. Fall and spring. 2 Lect. Prereq., Chemistry 111, 112. An introduction to the processes and calculations of chemical engineering.

5103. *CHEMICAL ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Fall. 3 Lect. Prereq., Chemistry 403, 404. The development of the fundamental principles of thermodynamics, with special attention to their application to chemical engineering processes.

5104. *CHEMICAL ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 5103. Continuation of 5103.

5106. *CHEMICAL ENGINEERING KINETICS.* Credit 2 hrs. Spring. 2 Lect. Prereq., 5104. The kinetics of chemical engineering reactions and processes.

5203, 5204. *CHEMICAL ENGINEERING TECHNOLOGY.* Credit 2 hrs. Fall and spring. 2 Lect. A discussion of the important chemical engineering processes and industries. The first term is devoted to the consideration of inorganic chemical technology; in the second term, the discussion deals with the organic chemical engineering industries.

5303, 5404. *UNIT OPERATIONS OF CHEMICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 3 Lect. Prereq., or parallel courses, Chemistry 403 and Engineering 5203 and 5204. A critical discussion of the unit operations of chemical engineering.

5353, 5354. *UNIT OPERATIONS LABORATORY.* Credit 3 hrs. Fall and spring. Prereq., 5303, 5304.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS.* Credit 2 hrs. Fall and spring. 2 class periods. Prereq., or parallel course, 5304. Problems in fluid flow and heat transfer; distillation; evaporation; drying; humidification and air conditioning; and infiltration.

5505. *ADVANCED PROBLEMS IN HEAT TRANSFER.* Credit 2 hrs. Spring. 2 class periods. Prereq., 5503 or equivalent. Advanced topics in heat transfer. Heat transfer to fluids in streamline flow; heat transfer under unsteady-state conditions; heat transmission in mixed-flow heat exchanges, etc. Primarily for graduate students.

5506. *ADVANCED PROBLEMS IN DIFFUSIONAL OPERATIONS.* Credit 3 hrs. Fall. 3 class periods. Prereq., 5503, 5504, or equivalent. Primarily for graduate students. Advanced topics in distillation; gas absorption; liquid-liquid extraction; and drying.

5603, 5604. *CHEMICAL ENGINEERING EQUIPMENT.* Credit 2 hrs. Fall and spring. 2 Lect. Prereq., 5304. Details of design and construction of chemical engineering equipment; piping; design of pressure vessels; detailed design of process equipment.

5605, 5606. *CHEMICAL PLANT DESIGN.* Credit 2 hrs. Fall and spring. Individual problems in the design of complete chemical plants, with estimation of costs of construction and operation.

5701. *PLANT INSPECTIONS.* Credit 1 hr. Spring. A series of supervised inspection trips to manufacturing plants representing various chemical engineering industries. Each student is required to submit a critical and comprehensive report.

5711. *LIBRARY USE AND PATENTS.* Credit 1 hr. Fall. The effective use of technical literature; literature searches; abstracts and bibliographies; patent law.

5741. *PETROLEUM REFINING.* Credit 3 hrs. Alternate terms. 3 Lect. Prereq., 5304. Processes employed in petroleum refining.

5742. *TECHNOLOGY OF HIGH POLYMERS.* Credit 3 hrs. Alternate terms. Prereq., Chemistry 404. Polymerization reactions, manufacture and properties of synthetic resins, fibers, plastics, and rubbers.

5745. *CONTROL OF ENGINEERING PROCESSES.* Credit 3 hrs. Fall. 3 Lect. Hours to be arranged. Prereq., 5304 and 5354, or 6204 and 6254. The methods used for operation control and quality control in chemical engineering processes.

5746. *CHEMICAL ENGINEERING ECONOMICS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 5304, or special permission. The economic aspects of research, development, manufacturing, and sales in the chemical industries.

5851. *CHEMICAL MICROSCOPY.* Credit 3 hrs. Either term. 1 Lect. and 2 lab. periods. Prereq., or parallel courses, Chemistry 403, 404, or 407, 408 and Physics 117, 118, or special permission. The use of microscopes and their accessories in chemical and technical investigations. Micrometry; quantitative estimations; microscopical characteristics and physical chemistry of crystals; lens systems and photomicrography; study of industrial materials.

5853. *MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC).* Credit 2 hrs. or more. Either term. Prereq., 5851. Laboratory periods to be arranged. Laboratory practice in the analysis of inorganic substances containing the more common elements.

5859. *ADVANCED CHEMICAL MICROSCOPY.* Credit 1 hr. or more. Either term. Prereq., 5851 and special permission. Laboratory practice in special methods and special applications of chemical microscopy.

5953, 5954. *SENIOR PROJECT.* Credit 3 hrs.; additional credit by special permission. Fall and spring. Prereq., 5304. Research on an original problem in chemical engineering.

5955. *SPECIAL PROJECTS IN CHEMICAL ENGINEERING.* Credit variable. Either term. Prereq., 5954. Research or studies of special problems in chemical engineering.

## METALLURGICAL ENGINEERING

6110. *CASTING, WORKING, AND WELDING OF METALS.* Credit 2 hrs. Either term. 1 Lect. and 1 lab. period. An elementary course covering the important industrial processes used in the casting, hot working, cold forming, and welding of metals. The utilization of metallurgical processes in other branches of engineering is stressed.

6111. *INTRODUCTORY METALLURGY.* Credit 2 hrs. Fall. 1 Lect. and 1 lab. period. For students in metallurgical engineering. An introduction to the principles of metallurgy. Covers a number of metallurgical processes and includes laboratory work in casting, metal working, welding, and heat treatment.

6113. *METALLURGY OF CASTING, WORKING, AND WELDING.* Credit 2 hrs. Fall. 2 Lect. Prereq., 1231, 6110. An advanced course for students in mechanical engineering covering the application of metallurgical principles to foundry, metal working, and welding problems.

6114. *METALLURGY OF CASTING, WORKING, AND WELDING.* Credit 3 hrs. Spring. 3 Lect. and 1 lab. period. Prereq., 6111, 6811. For students in metallurgical engineering. A critical study of selected processes in the fields of casting, metal forming and working, welding, and power metallurgy. Emphasis is placed on the metallurgy principles involved, the metallurgical factors governing control of the processes, and the influence of the processing methods on the final products.

6120. *ADVANCED FOUNDRY ENGINEERING.* Credit 3 hrs. Fall. 3 class periods including special laboratory studies. Prereq., 6113 or 6114. Critical study of foundry technology and the metallurgical features of cast metals. Laboratory investigation of special foundry processes and procedures.

6203, 6204. *SMELTING AND REFINING.* Credit 3 hrs. Fall and spring. 3 Lect. Prereq., Chemistry 404 and Engineering 1256, 6501. A study of methods of extraction of metals and alloys of commerce. Consideration is given to principles of ore beneficiation and to fundamentals of metallurgical practice, including details of production and utilization of heat. The commercial processes for the reduction and refining of individual metals together with limitations and problems arising from these processes are analyzed. A detailed consideration of the furnace operations in the manufacture of iron and steel illustrates the application of physicochemical principles to the industrial production of useful alloys.

6221. *ADVANCED PROCESS METALLURGY.* Credit 2 hrs. Fall. 2 class periods. Prereq., 6203, 6204. An advanced course covering production of metals and alloys. Emphasis on the application of thermodynamics to the study of the extraction and refining of metals.

6253, 6254. *UNIT PROCESSES IN METALLURGY.* Credit 3 hrs. Fall and spring. 1 Lect. and 1 lab. period with reports. Parallel courses, 6203, 6204. Experimental study of important processes in metallurgy, including ore dressing, temperature measurements, generation and control of furnace atmospheres, furnace design and performance, smelting and refining operations and electrodeposition. Reports based on the experimental data, discussing the principles involved in the operations, are an important part of the course.

6311, 6312. *PHYSICAL METALLURGY.* Credit 2 hrs. Fall and spring. Prereq., 6811. Detailed discussion of plastic deformation, recrystallization and grain growth,

diffusion in alloys, precipitation from solid solution, and transformation mechanisms in heat treatment.

6351. *PHYSICAL METALLURGY LABORATORY.* Credit 3 hrs. Fall. Labs with conferences. Parallel course, 6311. Theory and metallurgical application of X-ray diffraction, and experiments to illustrate the important phenomena of physical metallurgy and techniques for their investigation. Determination of lattice types, parameter measurements, pole figures, and single crystal orientation by X-ray methods.

6501. *METALLURGICAL CALCULATIONS.* Credit 2 hrs. Fall. 2 class periods. Prereq., 1255. An introductory course in the application of the principles of chemistry and physics to metallurgical problems, including combustion, heat balances, gas reactions, and furnace changes.

6602. *METALLURGICAL DESIGN.* Credit 3 hrs. Spring. 3 class periods. Prereq., 6312. Metallurgical and mechanical factors governing the selection of metals for various services. Analysis of service requirements, and the selection and fabrication of metals to fulfill such requirements; analysis of service failures of metals and remedies for such failures; and study of the merits and limitations of materials applications in existing products and equipment.

6701. *PLANT INSPECTION.* Credit 1 hr. Spring. A series of supervised inspection trips to manufacturing plants representing various metallurgical engineering industries. Each student is required to submit a comprehensive report.

6811. *INTRODUCTORY METALLOGRAPHY.* Credit 3 hrs. Spring. 1 Lect. and 2 lab. periods. Prereq., 1255 or 1222. Microstructures of alloys, as related to composition, thermal history, and physical properties. Preparation of specimens; principles and use of metallographic microscopes.

6953, 6954. *SENIOR PROJECT.* Credit 2 hrs. Fall and spring. Prereq., 6254. Research on an original problem in metallurgical engineering.

# AERONAUTICAL ENGINEERING

## UNDERGRADUATE COURSES

7001. *INTRODUCTION TO AERONAUTICAL ENGINEERING.* Credit 3 hrs. Given as required. Prereq., engineering mechanics. An introductory course for students in all branches of engineering. Emphasis on airplane mechanics; aerodynamic forces; airplane performance, airplane stability and control.

## GRADUATE COURSES

7101. *MECHANICS OF AIRPLANES.* Credit 3 hrs. Fall. Prereq., engineering mechanics. Physics of the atmosphere, properties of gases and fluids; similarity laws. Inviscid incompressible flow; momentum methods; vortices; introduction to airfoil and wing theory. Basic properties of compressible flow at subsonic, transonic, and supersonic speeds. Introduction to the methods of viscous flow theory; viscous drag; experimental methods. Estimation of airplane performance. Static longitudinal stability and control, stick-fixed and stick-free, power effects.

7102. *MECHANICS OF AIRPLANES.* Credit 3 hrs. Spring. Prereq., 7101. Dynamics of longitudinal motion; phugoid motion; longitudinal stability, stick-fixed and stick-free; stability criteria. Lateral dynamics; discussion of derivatives: lateral stability, controls fixed and free; discussion of modes. Autorotation and spin. Response to controls; operational methods; automatic stabilization and autopilot.

7203. *AERODYNAMICS OF POWER PLANTS.* Credit 3 hrs. Fall. Prereq., engineering thermodynamics. Cycle thermodynamics; the gas-turbine process. Thermodynamics of flow. Cycle and analysis of turbojets, ramjet, turboprop, ducted fan

afterburner, etc. Heat transfer by force convection at high speeds; gas properties, Reynolds analogy; radiator and heat-exchanger design. Elements of the jet-propulsion engine; combustion chamber; aerodynamic design of compressors and turbines. Rockets.

7204. *GASDYNAMICS.* Credit 4 hrs. Spring. Prereq., permission of the instructor. One-dimensional steady flow of a perfect gas with heat addition, etc., wave-propagation phenomena, method of characteristics for 2-dimensional and axi-symmetric supersonic steady flow and unsteady channel flow. Experimental methods.

7206. *SPECIAL TOPICS IN PHYSICAL GASDYNAMICS.* Credit 2 hrs. Given as required. Prereq., 8121, 8122, or equivalents, and 7204. A study of various gasdynamical problems in which the molecular kinetics plays an important role. Specific topics to be chosen by consultation.

7301. *THEORETICAL AERODYNAMICS I.* Credit 3 hrs. Six hours a week during the first half of the fall term. Prereq., differential equations, intermediate mechanics or introduction to theoretical physics. Introduction to theoretical hydrodynamics. Ideal fluids. The boundary-value problems of steady and nonsteady two- and three-dimensional potential flows with special attention to flows produced by the motion of solid bodies. Vector methods and complex variable are used extensively.

7302. *THEORETICAL AERODYNAMICS II.* Credit 3 hrs. Spring. Prereq., 7301. 7303. Wing theory; thin-airfoil theory, two-dimensional airfoil theory. Prandtl wing theory, lifting surfaces, general multiple theory, nonstationary wing theory. Correction for compressibility (linearized theory). Wing theory for supersonic speeds; source and sink methods and extensions, conical-flow methods, nonstationary cases.

7303. *THEORETICAL AERODYNAMICS III.* Credit 3 hrs. Six hours a week during the second half of the fall term. Prereq., 7204, 7301. The aerodynamics of compressible fluids; equations of motion, small-perturbation theory (subsonics and supersonic); Janzen-Rayleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow.

7304. *THEORETICAL AERODYNAMICS IV.* Credit 3 hrs. Spring. Prereq., 7301. The aerodynamics of viscous fluids: the boundary layer, heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Experimental methods.

7305. *AERODYNAMICS OF COMPRESSIBLE VISCOUS FLUIDS.* Credit 2 hrs. Fall. Prereq., 7304. The theory of boundary layers and heat transfer in compressible fluids. Phenomena of interaction between shock waves and boundary layer. Experimental methods.

7306. *THEORY OF PROPELLERS AND ROTORS.* Credit 1 hr. Spring. Prereq., 7101 or equivalent. Momentum and blade-element theories, Glauert-Betz theory of lightly loaded propellers and other theories; two-dimensional cascades; application to compressors; fans and turbines; application to helicopters.

7401. *AIRPLANE STRUCTURES.* Credit 3 hrs. Fall. Prereq., strength of materials. Stress analysis of typical airplane structures: trusses, frames, wing structures. Torsion. Shear. Use of stress function. Plastic failure. Failure by buckling: stability of thin-walled structures, theory of shells.

7402. *AIRPLANE STRUCTURES.* Credit 3 hrs. Spring. Prereq., strength of materials. Fatigue: stress concentration, mechanical vibrations. Impact stresses: response of transient loading conditions. Influence of elastic deformations on aerodynamic loads: static divergence. Wing flutter.

7403. *AIRPLANE DESIGN.* Credit 1 hr. Fall. Orientation: the airplane and its components; the philosophy of airplane design; aircraft materials and processes.

7404. *AIRPLANE DESIGN.* Credit 1 hr. Spring. Prereq., 7403. Orientation (continued).

7405. *AERO-ELASTIC PROBLEMS.* Credit 1 hr. Spring. Prereq., 7101 and 7102. Wing divergence and aileron reversal for straight and swept wings. Gust loads on the elastic airplane. Flutter calculations. Discussion of flutter modes involving control-surface vibration.

7406. *SPECIAL METHODS OF STRUCTURAL ANALYSIS.* Credit 2 hrs. Given as required. Prerequisites, 7401 and 7402. Problems in impact stress distribution. Aero-elastic problems. Wing flutter with two and three degrees of freedom.

7407. *DYNAMICS OF STRUCTURES.* Credit 3 hrs. Given as required. Prereq., strength of materials. Vibrations, impact, transverse impact. Properties of materials as functions of rate of load. Fundamentals of plasticity. Dynamic failure. Some laboratory work will be required.

7801. *RESEARCH IN AERONAUTICAL ENGINEERING.* (Credit to be arranged.) Prereq., admission to the Graduate School of Aeronautical Engineering and approval of the Director. Independent research in a field of aeronautical science. Such research must be under the guidance of a member of the staff and must be of a scientific character.

7901. *AERONAUTICAL ENGINEERING COLLOQUIUM.* Credit 1 hr. Prereq., admission to the Graduate School of Aeronautical Engineering. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory, and visiting scientists on topics of interest in aeronautical science, especially in connection with new research.

7902. *ADVANCED SEMINAR IN AERONAUTICS.* Credit 2 hrs. Prereq., approval of the Director. Same as 7901 but devoted to topics of advanced scientific interest.

## ENGINEERING PHYSICS

8010. *APPLIED NUCLEAR AND REACTOR PHYSICS.* Credit 3 hrs. Spring. 3 Rec. Prereq., sophomore physics and mathematics. Atomic and nuclear structure, binding energy, isotopes, characteristics of high energy machines, nuclear reactions, cross sections, artificial transmutations and uses thereof, properties of neutrons, interactions of neutrons with matter, nuclear fission and nuclear reactors, elementary reactory theory, types of reactors, problems in reactor design, instruments for detection and measurement, protection for personnel, radioactive tracer techniques and application to engineering problems.

8051 and 8052. *PROJECT.* Terms 9 and 10. Credit 3 hrs. Fall and spring. Informal study under direction of a member of the University staff. The objective is to develop self-reliance and initiative, as well as to gain experience with methods of attack and with over-all planning, in the carrying out of a special problem related to the student's field of interest. The choice of a problem is to be made by the student in consultation with members of the staff.

8090. *INFORMAL STUDY IN ENGINEERING PHYSICS.* Fall or spring. Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff. Hours to be arranged.

8121. *CLASSICAL THERMODYNAMICS.* Credit 3 hrs. Fall. 3 Rec. Primarily for candidates for the degree of Bachelor of Engineering Physics. Introduction to the kinetic theory of gases and brief introduction to statistical mechanics. Application to physical and engineering problems.

8122. *CLASSICAL THERMODYNAMICS.* Credit 3 hrs. Spring. 3 Rec. Continuation of 8121.

8512. *ELECTRON MICROSCOPY.* Credit 3 hrs. Spring. Prereq., consent of the instructor. Lect. Lab. Hours to be arranged. Basic electron optics, image formation

and interpretation, construction and operation of the electron microscope in physics, chemistry, and biology.

8517. *ELECTRON OPTICS AND ITS APPLICATIONS.* Credit 3 hrs. Fall. Prereq., Physics 225 (Physics 215 advised but not required). Electron beam formation, Gaussian dioptrics and aberrations of electron lenses, application including cathode, ray tube, electron microscope, beta ray spectrometer, mass spectrometer.

# GENERAL COURSES OF INSTRUCTION

Described in this section are certain courses prescribed for students in engineering, given in the College of Arts and Sciences, the College of Agriculture, or other divisions of the University as indicated below.

## MILITARY TRAINING

The University requirement in military training (see p. 16 above and the *Announcement of the Independent Divisions and Departments)* may be satisfied:

(a) by four terms of satisfactory work in the Department of Military Science and Tactics (Military Science 11, 12, 21, and 22); or

(b) by four terms of satisfactory work in the Department of Air Science (Air Science 1, 2, 3, 4); or

(c) by four terms of satisfactory academic work (Naval Science 101, 102, 201, and 202) in the Department of Naval Science. (According to their respective contractual agreements with the Navy, Regular and Contract NROTC students are committed to continue in the NROTC program for four years.)

Students who have been enrolled in the armed services are exempted from the requirement in military training. For exemptions on other grounds, consult the *Announcement of the Independent Divisions and Departments.*

Advanced courses of two years in military science and tactics and air science are elective and may qualify students for appointments as Second Lieutenants in the Regular Army or Air Force, the Officers Reserve Corps, U.S. Army, or the U.S. Air Force Reserve.

The Department of Naval Science offers a four-year course of training which may qualify students for appointments as Ensigns in the Regular Navy or Naval Reserve or as Second Lieutenants in the Marine Corps or Marine Corps Reserve.

Academic credit of three hours a term may be earned in the advanced courses in military science and tactics and air science. This credit may be applied toward any of the free electives offered in the curricula of the College of Engineering. Students who complete the four-year course in naval science are given University credit for twenty-four hours of college work. At present, net credit toward degree requirements of the various schools of the College of Engineering is as follows: School of Mechanical Engineering, at least 9 hours (Option B, 6 hours); School of Electrical Engineering, 12 hours; School of Chemical and Metallurgical Engineering, 12 hours; School of Civil Engineering, 12 hours; Department of Engineering Physics, 6 hours.

Further details concerning the courses offered in military training may be obtained in the *Announcement of the Independent Divisions and Departments.*

## PHYSICAL EDUCATION

The University requirement in physical education (see p. 16 above and the *Announcement of the Independent Divisions and Departments)* may be satisfied by four terms of work in the Department of Physical Education. For this purpose

Physical Education 1, 2, 3, and 4 are available to men, and Physical Education 51, 52, 53, and 54, to women. Additional courses in physical education are described in the *Announcement of the Independent Divisions and Departments.*

# ARCHITECTURE

## REGIONAL AND CITY PLANNING

(In cooperation with the School of Civil Engineering)

400, 401. *HISTORY OF ARCHITECTURE.* Throughout the year. Credit 3 hrs. a term. A course primarily intended for students who are not architects but who are interested in a brief survey of the history of architecture and its relationship with parallel social, economic, and political trends. No experience in drawing or knowledge of structural elements is required. Either or both terms may be taken for credit.

700. *HISTORY OF CITY PLANNING.* Fall. Credit 3 hrs. Open to graduates and upperclassmen. The history of the planning of communities from ancient times to the present. Lectures, assigned reading, and examinations.

710. *PRINCIPLES OF CITY AND REGIONAL PLANNING.* Fall. Credit 3 hrs. Open to graduates and upperclassmen. A review of the basic influences in the development of cities. A general view of the theory and accepted practice of city and regional planning, including a study of the social, economic, and legal phases. Lectures, assigned reading, and examinations.

711. *CITY PLANNING PRACTICE.* Spring. Credit 3 hrs. Prereq., Course 710. The procedures and techniques of gathering and analyzing data for municipal planning studies. The selection and integration of data for use in planning. Practical application of the theories of city planning. Office practice. Lectures, assigned readings, reports.

713. *HOUSING.* Fall. Credit 2 hrs. Registration limited. Prereq., Course 710. An introduction to the theory and standards of housing practice through analysis and comparison of various existing examples, considering the social, economic, and technical sides of the work. Lectures, assigned readings, and reports.

715. *PUBLIC PROBLEMS IN URBAN LAND USE.* Fall. Credit 2 hrs. Prereq., Course 710. Urban land policies, rent, taxation, and market factors.

717. *PLANNING AND ZONING LAW.* Spring. Credit 2 hrs. Prereq., Course 710. Technical and legal aspects of preparing and administering zoning ordinances. Examination of other legal problems in planning, including subdivision control, official map procedure, regulation of roadside development, and building and housing codes.

718. *CITY PLANNING DESIGN.* Fall. Credit 8 hrs. Limited to graduate students and, by permission, to seniors who may substitute it for Design 108. Students are assigned a series of design problems as a means of introduction to the basic principles of large-scale site planning. Lectures, discussions, and group and individual criticism.

720. *FIELD PROBLEM IN URBAN PLANNING.* Fall. Credit 8 hrs. Group study of an existing community and the preparation of a general plan for its development. Investigation of population trends, economic base, and regional influences. Land use analysis, and studies of traffic flow, recreation facilities, housing conditions, school and public building locations, automobile parking, public transportation and other elements of the community. Preparation of recommendations for carrying out the general plan. Lectures, discussions, field trips, preliminary and final reports.

## CHEMISTRY

105–106. *GENERAL CHEMISTRY.* Throughout the year. Credit 3 hrs. a term. Chemistry 105 is prerequisite to Chemistry 106. For those students who will take more chemistry, it serves as a prerequisite to the more advanced courses. Open to those who have had or have not had high school chemistry. May be elected by students who do not intend to take more chemistry. The important chemical principles and facts will be covered, with considerable attention given to the quantitative aspects and to the techniques which are important for further work in chemistry.

111–112. *INTRODUCTORY INORGANIC CHEMISTRY.* Throughout the year. Credit 3 hrs. a term. Chemistry 111 is prerequisite to Chemistry 112. Chemistry 115–116 must be taken with Chemistry 111–112, except by consent of the instructor. Open to those students who have offered high school chemistry for entrance. Required of candidates for the degree of B.Ch.E. and recommended for candidates for the degree of A.B. with a major in chemistry. A study of the concepts and laws of inorganic chemistry and a systematic treatment of the common elements and their compounds based on atomic structure and the Periodic System.

115–116. *INTRODUCTORY INORGANIC LABORATORY AND QUANTITATIVE ANALYSIS.* Throughout the year. Credit 3 hrs. a term. Chemistry 115 is prerequisite to Chemistry 116. Must be taken with Chemistry 111–112. The theories of chemistry are applied in a study of the preparation and properties of the common elements and their compounds and to the separation and detection of their ions.

224. *INTRODUCTORY QUANTITATIVE ANALYSIS.* Either term. Credit 4 hrs. Prerequisite, Chemistry 201, or 112 and 116. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. A study of the fundamental principles of gravimetric and volumetric analysis, with practice in stoichiometry, and the analyses of a variety of substances by volumetric, gravimetric, and colorimetric methods.

301. *INTRODUCTION TO ORGANIC CHEMISTRY.* Fall. Credit 2 hrs. Prereq., Chemistry 106. For students in engineering. A brief survey of the principal classes of organic compounds, their industrial sources, manufacture, and utilization.

307–308. *INTRODUCTORY ORGANIC CHEMISTRY.* Throughout the year. Credit 3 hrs. a term. Prereq., Chemistry 106 or 112. Qualitative analysis is desirable but not required. Chemistry 307 is prerequisite to Chemistry 308. Chemistry 311–312 must be taken with Chemistry 307–308. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. A systematic study of the more important compounds of carbon, their occurrence, methods of synthesis, relations, and uses.

311–312. *INTRODUCTORY ORGANIC LABORATORY.* Throughout the year. Credit 2 hrs. a term. Chemistry 311 is prerequisite to Chemistry 312. Must be taken with Chemistry 307–308. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. The student prepares typical compounds of carbon and familiarizes himself with the properties, reactions, and relations.

402. *INTRODUCTION TO PHYSICAL CHEMISTRY.* Spring. Credit 2 hrs. Prerequisite, Chemistry 106. Prerequisite or parallel courses, Mathematics 163 or 193 and Physics 117. For students in civil and mechanical engineering. An additional recitation period will be arranged for engineering physics students and others who wish to obtain three hours credit for the course. A brief survey of physical chemistry. Problems of interest to students in engineering will be discussed.

403–404. *INTRODUCTORY PHYSICAL CHEMISTRY.* Throughout the year. Credit 3 hrs. a term. Prerequisite, Chemistry 224 and 308, Mathematics 163 or 193, and Physics 118. Chemistry 403 is prerequisite to Chemistry 404. Required of candidates for the degree of B.Ch.E. A systematic treatment of the fundamental principles

of physical chemistry. The laws of thermodynamics and of the kinetic theory are applied in a study of the properties of gases, liquids, and solids, thermochemistry, properties of solutions, and equilibrium in homogeneous and heterogenous systems. Chemical kinetics and atomic and molecular structure are also studied.

411–412. *INTRODUCTORY PHYSICAL LABORATORY.* Throughout the year. Credit 2 hrs. a term. Prereq. or parallel course, Chemistry 403–404 or 407–408. Chemistry 411 is prerequisite to Chemistry 412. Enrollment may be limited. Required of candidates for the degree of B.Ch.E. and A.B. with a major in chemistry. Quantitative experiments illustrating the principles of physical chemistry, and practice in performing typical physiochemical measurements. A part of the scheduled time is used for the discussion of experiments rather than for laboratory work.

## ECONOMICS

105. *MODERN ECONOMIC SOCIETY.* Either term. Credit 3 hrs. Open to a limited number of freshmen. A survey of the existing economic order, its more salient and basic characteristics, and its operations.

203. *MONEY, CURRENCY, AND BANKING.* Fall. Credit 3 hrs. Prereq., Economics 106. A study of our currency system and banking processes for the primary purpose of training the student to determine the influence of monetary factors in economic problems.

## ENGLISH

111–112. *INTRODUCTORY COURSE IN READING AND WRITING.* Throughout the year. Credit 3 hrs. a term. Open to freshmen, English 111 is prerequisite to 112. The aim of this course is to increase the student's ability to communicate his own thought and to understand the thought of others.

*ENGLISH FOR FOREIGNERS*

*The following two courses are offered by the Division of Modern Languages. Foreign students should consult a member of that division in Morrill Hall 108.*

102. *ENGLISH FOR FOREIGNERS.* Fall. Credit 6 hrs. Prereq., placement by the instructor. Hours to be arranged.

211. *ENGLISH FOR FOREIGNERS.* Fall. Credit 6 hrs. Prereq., a satisfactory proficiency examination. Hours to be arranged.

## GEOLOGY

113. *ENGINEERING GEOLOGY.* Either term. Credit 3 hrs. Students who have had Geology 101–102 or 115 may take 113 for one hour credit. The purpose of the course is to provide a geologic background so that the engineer will be competent to adapt his work to conform with the limitations imposed by geologic conditions.

712. *METALLURGICAL RAW MATERIALS.* Fall. Credit 3 hrs. For second year students in metallurgical engineering. The properties, occurrence, associations, distribution, and economic aspects of the commercially important ore, refractory, and fluxing materials that enter metallurgical operations.

## HISTORY

165–166. *SCIENCE IN WESTERN CIVILIZATION.* Throughout the year. Credit 3 hrs. a term. A survey of the development of science in its relation to European and American civilization. Primarily for engineers and science majors, but open to other qualified upperclassmen.

## INDUSTRIAL AND LABOR RELATIONS

293. *SURVEY OF INDUSTRIAL AND LABOR RELATIONS.* Either term. Credit 3 hrs. A survey for students not in the School of Industrial & Labor Relations. An analysis of the major problems in industrial and labor relations: labor union history, organization, and operation; labor market analysis and employment practices; industrial and labor legislation and social security; personnel management and human relations in industry; collective bargaining; mediation and arbitration; the rights and responsibilities of employers and employees; the major governmental agencies concerned with industrial and labor relations.

## MATHEMATICS

161. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit 3 hrs. Prereq., trigonometry and intermediate algebra. Hours to be arranged. Plane analytic geometry through conics. Differentiation and integration of polynomials with applications to rates, maxima, volumes, pressures, etc.

Courses 161–162–163 represent a standard three-term calculus sequence, presenting the main ideas and techniques of the calculus and analytic geometry; the material is so arranged that the first two terms (161–162) provide a reasonably complete introduction to the subject. This sequence of courses is not intended as preparatory to more advanced courses in mathematics, although admission to such courses can be obtained following this sequence by special permission. (For students who took the 161–162–163 sequence when it was the only one offered, this will continue to serve as the prerequisite to advanced work.) Students majoring in mathematics or in those physical sciences where mathematics is extensively used or who have special mathematical competence should elect the 181–182–183 sequence instead.

162. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit 3 hrs. Prereq., Mathematics 161. Hours to be arranged. Differentiation and integration of algebraic, trigonometric, logarithmic, and exponential functions, with applications. Related topics, including polar coordinates, parametric equations, and vectors.

163. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit 3 hrs. Prereq., Mathematics 162. Hours to be arranged. Infinite series, solid analytic geometry, partial derivatives, and multiple integrals.

181. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit 3 hrs. Prereq., trigonometry and intermediate algebra. Hours to be arranged. The range of topics will be similar to that of Mathematics 161, but each will be covered more intensively. Intended primarily for students of superior mathematical ability. (See remarks under Mathematics 161 above.)

182. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit 3 hrs. Prereq., Mathematics 181. Hours to be arranged.

Topics similar to those of Mathematics 162.

183. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit 3 hrs. Prereq., Mathematics 182. Hours to be arranged.

Topics similar to those of Mathematics 163.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS.* Either term. Credit 3 hrs. Prereq., Mathematics 163. Solution of ordinary differential equations by analytic and numerical methods.

611–612. *HIGHER CALCULUS.* Throughout the year. Credit 3 hrs. a term. Prereq., Mathematics 201. First term prerequisite to second. Primarily for undergraduates. Partial differentiation, multiple and line integrals, Fourier series, partial differential equations, vector analysis, complex variables, calculus of variations, Laplace transforms. Emphasis is placed on a wide range of formal applications of

the calculus, rather than on the logical development. The second term will be accepted as prerequisite to complex variables.

613–614. *METHODS OF APPLIED MATHEMATICS.* Throughout the year. Credit 3 hrs. a term. Prereq., Mathematics 201. Primarily for undergraduates. The first two terms of a proposed four-term course, intended for students who wish to go beyond Mathematics 611–612. Topics to be covered are vector analysis, calculus of functions of several variables, infinite series, and introduction to complex variables. Fourier series and integrals, Laplace transforms. It is expected that the succeeding course, Mathematics 614–615, will cover complex variable theory, partial differential equations, special functions, calculus of variations, matrix theory. Also, Mathematics 613–614 will be a good preparation for Mathematics 621–622.

621–622. *MATHEMATICAL METHODS IN PHYSICS.* Throughout the year. Credit 4 hrs. a term. Prereq., a good knowledge of the techniques of the calculus, such as given by 611–612 or 613–614, and at least two years of general physics. First term prerequisite to second. For graduate students and qualified undergraduates. Lectures and problem work designed to give the students a working knowledge of the principal mathematical methods used in advanced physics.

## PHYSICS

113. *ELECTRICITY AND MAGNETISM.* Fall. Credit 2 hrs. Prereq., Physics 115, 116, calculus or simultaneous registration in Mathematics 163. One recitation and one discussion period a week to be arranged and one laboratory period of 2½ hours on alternate weeks to be arranged. For students of civil engineering only. Survey of the fundamental laws of electric and magnetic fields, electric circuits, induced emfs, inductance, and capacitance. The laboratory experiments are illustrative of the topics mentioned.

114. *PHYSICAL OPTICS AND ATOMIC PHYSICS.* Spring. Credit 2 hrs. Prereq., Physics 113. One recitation and one discussion period a week to be arranged, and one laboratory period of 2½ hours in alternate weeks to be arranged. For students of civil engineering only. Survey of electromagnetic waves and their applications to optical phenomena. Survey of selected topics in atomic and nuclear physics, electronic emission, and photoelectricity. The laboratory experiments are illustrative of the topics mentioned.

*Note:* Physics 115, 116, 117, and 118 form a sequence in a two-year continuous course in General Physics required of all students of engineering who are candidates for the degree of B.Ch.E., B.E.E., B.Eng.Phys., and B.M.E. Physics 115, 116, 113, and 114 constitute the corresponding sequence for candidates for the degree B.C.E. Demonstrations, theory, experiments, and problem drill. One lecture, two recitations, and one laboratory period a week, as assigned. Consult instructor in charge for available recitation and laboratory periods.

115. *MECHANICS.* Fall. Credit 3 hrs. Prereq., calculus or simultaneous registration in Mathematics 161. Entrance physics is desirable but not required. Kinetics, statics, elasticity, liquids, and mechanics of gases. The laboratory work consists of measurements related to the above topics.

116. *HEAT, SOUND, AND GEOMETRICAL OPTICS.* Spring. Credit 3 hrs. Prereq., Physics 115, calculus, or simultaneous registration in Mathematics 162. Temperature, calorimetry, change of state, heat transfer, thermal properties of matter, elementary thermodynamics, wave motion, vibrating bodies, acoustical phenomena, geometrical optics, reflection, refraction, mirrors, and lenses. The laboratory work consists of measurements related to the above topics.

117. *ELECTRICITY AND MAGNETISM.* Fall. Credit 3 hrs. Prereq., Physics 115, 116, calculus, or simultaneous registration in Mathematics 163. Introductory study

of the fundamental laws of electric and magnetic fields and their applications to elementary circuit problems. Electrostatic fields and potential; steady currents, induced emfs, inductance, dielectrics, capacitance, and simple transients. The laboratory work consists of basic measurements in direct current circuits.

118. *PHYSICAL OPTICS AND ATOMIC PHYSICS.* Spring. Credit 3 hrs. Prerequisite, Physics 117. Properties of electromagnetic waves and their application to optical phenomena; interference, diffraction, and polarization. Selected topics in atomic and nuclear physics; spectra, electron emission processes, radioactivity, and nuclear reactions. The laboratory work consists of basic experiments in physical electronics and physical optics.

208. *PHYSICAL MECHANICS AND PROPERTIES OF MATTER.* Spring. Credit 3 hrs. Prereq., Physics 115 and Mathematics 161 and 162. Primarily for candidates for the degree of Bachelor of Engineering Physics. Elements of kinematics; Newton's law; conservation laws; D'Alembert's principle; application to selected problems; hydrostatics; elementary fluid dynamics; viscosity.

210. *ADVANCED LABORATORY.* Either term. Credit 3 hrs. a term. Prereq., Physics 205 and 206 or the equivalent. Required for physics majors. About sixty different experiments are available among the subjects of mechanics, acoustics, optics, spectroscopy, electrical circuits, electronics and ionics, heat, X-rays, crystal structure, solid state, cosmic rays, and nuclear physics. During the term the student is expected to perform five to ten experiments, selected to meet his individual needs. Stress is laid on independent work on the part of the student.

214. *ATOM, NUCLEAR, AND ELECTRON PHYSICS.* Spring. Credit 3 hrs. Two lectures and one recitation. Prereq., Physics 118 and Mathematics 607 or the equivalents. Primarily for students in electrical engineering. Two lectures and one recitation hour to be arranged. Elements of nuclear and atomic structure, fundamentals of quantum theory, basic kinetic theory of atoms and electrons; electronic processes with special reference to the electrical properties of metals, semiconductors, and insulators and general electron emission processes; elements of nuclear processes.

225. *ELECTRICITY AND MAGNETISM.* Fall. Credit 3 hrs. Prereq., Physics 117 or 204. Electrostatic and electromagnetic fields, polarization of dielectrics and magnetic media, displacement current, plane electromagnetic waves, the Poynting vector.

236. *ELECTRICITY AND MAGNETISM.* Spring. Credit 3 hrs. Prereq., Physics 225 and differential equations. Circuit theory from the standpoint of electromagnetic fields. Validity and limitation of circuit concepts. Steady and alternating currents in circuits and networks, distributed parameters, introductory high-frequency topics, high-energy machines.

242. *ANALYTICAL MECHANICS.* Spring. Credit 3 hrs. Prereq., Physics 203 and 208 and Mathematics 201, or their equivalents. Analytical mechanics of material particles, systems of particles and rigid bodies; planetary motion, stability of orbits; collisions; Euler's equations, gyroscopic motion; Lagrange's equations.

243–244. *ATOMIC, MOLECULAR, AND NUCLEAR PHYSICS.* Throughout the year. Credit 3 hrs. a term. Prereq., Physics 225 or consent of instructor. The fundamental particles of physics, statistical physics, the concepts of quantum mechanics, atomic structure and spectra, the periodic table, molecular structure and the chemical bond, properties of nuclei, nuclear reactions, interaction of radiation with nuclei.

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS.* Spring. Credit 3 hrs. Prereq., Physics 243. Lattice structure; specific heat; lattice energy; elastic properties; electric conduction; thermoelectric effects; contact potential; barrier effect; lattice defects; dielectric; magnetic and optical properties.

258. *MECHANICS OF CONTINUA.* Spring. Credit 3 hrs. Prereq., partial differential equations or consent of the instructor. Hours to be arranged. Equations of

state for gases, liquids, solids. Stress-strain relations for continuous media and equations of motion. Special topics in statics of elastic media. Waves and oscillations in continuous media. Topics in flow, and nonlinear phenomena in gases and fluids.

475. *THEORETICAL MECHANICS.* Fall. Credit 3 hrs. Prereq., Physics 242 or its equivalent.

## PSYCHOLOGY

101. *INTRODUCTION TO PSYCHOLOGY.* Either term. Credit 3 hrs. Open to freshmen. Two lectures plus either a third lecture or a recitation section each week, as announced. An introduction to the scientific study of behavior and experience, covering such topics as perception, motivation, emotion, learning, thinking, personality, and individual differences. This course is prerequisite to further work in the Department.

## PUBLIC SPEAKING

101. *PUBLIC SPEAKING.* Either term. Credit 3 hrs. Not open to freshmen. This course is designed to help the student express his convictions clearly and effectively in oral discourse. Study of basic principles of expository and persuasive speaking with emphasis on selection, evaluation, and organization of materials, and on simplicity and directness of style and delivery. Practice in preparation and delivery of speeches on current issues, in reading aloud, and in chairmanship; study of examples; conferences. Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Mr. THOMAS or Mr. R. W. ALBRIGHT before registering.

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